BAOJ Nanotechnology

J Antony Pradeep, et al., BAOJ Nanotech 2017, 3: 2
3: 017

Review

A Performance Comparision of Nanofluids Using Solar Flat Plate Collector and Flow is Simulated in Computational Fluid Dynamics (Cfd) Analysis

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Abstract

Flat Plate Collector (FPC) is widely used for domestic hot-water, space heating/drying and for applications requiring fluid temperature less than 100°C. Nanofluids are one of the combination of fluid and Nano-sized solid particles which are relatively used for some advanced applications .The mixture of Nanofluids and water to increase temperature difference and improve the efficiency of heating. And flat plate collector was used to produce heat through the copper tube and to sustain the heat which is not affected by the surroundings. To improve the performance and conductivity by Aluminium nitride and silicon carbide Nanofluids. This has more thermal conductivity it will improve the efficiency of heating. This results in increasing temperature and reduces the consumption of electricity. The output of the water, which is measured by thermocouple and results are tabulated and plotted on the graph. Then the results are analyzed in CFD (Computational Fluid Dynamics).

Keywords: Aluminium Nitride, Silicon Carbide, Flat Plate Collector, Thermocouple

Introduction

Now a day's using of more fossil fuels, it reduces the nature and fossil fuels. Coal is the major source of fossil fuel. By using in thermal power plants, which produce more pollution by ash content. In order to rectify these kind of problems we are taken a step to renewable energy. The Current situation in this world will meets the demand because of population. So we have to develop some renewable energy resources. The future generation will be

saving to explore the alternative energy sources like solar energy, hydrogen based fuel etc,. to fulfill their requirements. The solar energy option has been identified as one of the promising alternative energy sources for the future.

Solar Energy

Solar energy is radiant light and heat from sun that is harnessed using a range of ever-evolving technologies such as solar heating photovoltaic's solar thermal energy, solar architecture, molten salt power plants and artificial photosynthesis.

Solar Radiation

Solar radiation is the electromagnetic radiation emitted by the sun (in particular infrared, visible and ultrasonic light). Solar radiation includes wide range of wavelength but we will be concerned preliminary radiation in the wavelength range of 0.23-3µm. they gather sun's energy and transform its radiation into heat then transfer that heat into a the fluid.

Types of Solar Collectors

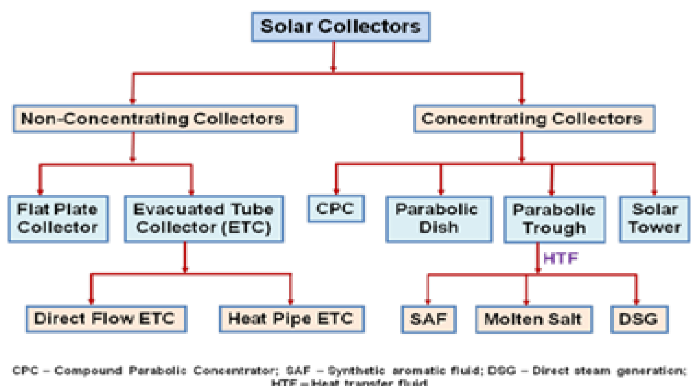

Fig.1 Types of solar collectors

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Sub Date: October 16th 2017, **Acc Date:** November 29th 2017, **Pub Date:** November 30th 2017

Citation: J Antony Pradeep and S Dhinesh kumar and D Balasubramanian (2017) A Performance Comparision of Nanofluids Using Solar Flat Plate Collector and Flow is Simulated in Computational Fluid Dynamics (Cfd) Analysis. BAOJ Nanotech 3: 17.

Flat Plate Collector

Flat-plate collectors are the most common solar collector for solar water-heating systems in homes and solar space heating [1]. These collectors are heating a liquid or air at temperatures less than 80°c. But Flat plate collectors easily attain temperatures of 40 to 70°c. A typical flat-plate collector is an insulated metal box with a glass or plastic cover (called the glazing) and a dark-colored absorber plate.

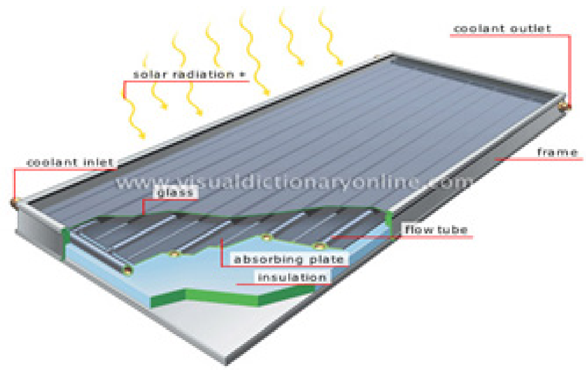


Fig.2 Flat plate collector

Elements in FPC

- Absorber plate
- The transparent cover
- The collector insulator
- The heat transfer medium

Design Factors in FPC

The performance of solar collector is defined as an energy balance Energy from Solar incident radiation into Energy absorbed. Here losses have considered a thermal energy loss to the surroundings from the collector by means of conduction convection radiation. The performance of solar collectors are analyzed by ASHRAE standard [2].

The steady state thermal efficiency of flat plate collector is calculated from

$$\eta = Q_u / A_c G_T$$

The amount of useful energy come out from the collector is the difference between the absorbed solar radiation and thermal losses

$$Q_u = A_C[S - U_L(T_P - T_a)]$$

Where,

S - Solar energy absorbed by a collector

G_T - Incident solar energy

U_L - Heat transfer coefficient

T_p - Mean absorbed plate temperature

T_a - Ambient temperature

A_c - Collector area

Nano

Nano Technology

Nanotechnology ("nanotech") is manipulation of matter on an atomic, molecular and supramolecular scale. Nanotechnology is a multidisciplinary science and technology and encompasses physical, chemical, biological, engineering and electronic process [3].

Applications of Nanotechnology

- Nanomedicine
- Nanobiotechnology
- Green nanotechnology
- Energy applications of nanotechnology
- Industrial applications of nanotechnology
- Potential applications of carbon nanotubes
- Nanoart

Nanomaterials

Nano-sized material having at least one external dimension in the size range of 1-100 nanometers. Nanomaterials include nanoparticles, nanostructured materials and ultrafine particles and other agglomarates and aggregates [3]..

Types of Nanomaterials

- Zero dimensional(0D) [Gold & quantum dots]
- One dimensional(1D) [Nanowire & nanotubes]
- Two dimensional(2D) [Nanosheets & nanowalls]
- Three dimensional(3D) [bulk materials]

Synthesis of Nanomaterials

Materials scientists are conducting research to develop novel materials with better properties, more functionality and lower cost than the existing one.

Several physical, chemical methods have been developed to enhance the performance of Nanomaterials displaying improved properties with the aim to have a better control over the particle size, distribution.

Development of synthesis protocols for realizing Nanomaterials over a range of sizes, shapes, and chemical compositions is an important aspect of nanotechnology.

Methods of Synthesis

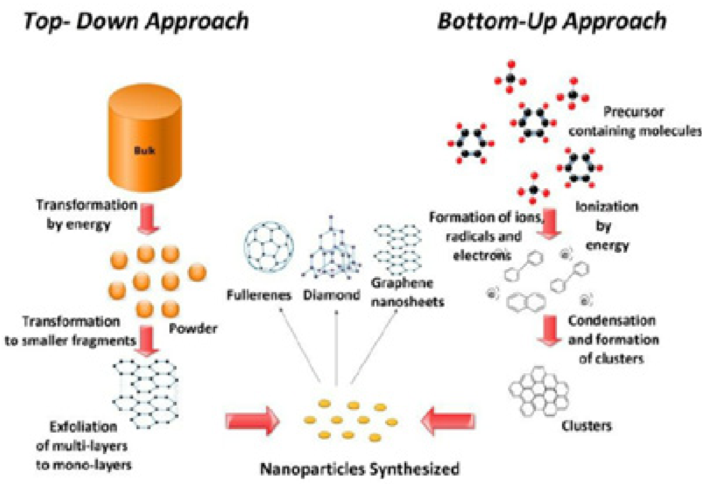


Fig.3 Method of synthesis

Top Down Approach: These approaches use larger (macroscopic) initial structures, which can be externally controlled in the processing of nanostructures.

Example: Etching through the mask ball milling and application of severe plastic deformation.

Bottom up Approach: This approach refers to the build-up of a material from the bottom: atom-by-atom, molecule-by-molecule or cluster-by-cluster. This route is more often used for preparing most of the nano-scale materials with the ability to generate a uniform size, shape and distribution.

Example: Quantum dot formation during epitaxial growth and formation of nanoparticles from colloidal dispersion.

Nanofluids

Heat transfer efficiency can also be improved by increasing the thermal conductivity of the working fluid Nanofluids are the cooling medium of the future with enhanced thermo physical properties and heat transfer performance can be applied in many devices for better performances. This article discusses the application potentials of nanofluids in solar water heating systems.

Properly engineered nanofluids possess the following advantages:

- High specific surface area and therefore more heat transfer surface between particles and fluids.
- High dispersion stability with predominant Brownian motion of particles.
- Reduced pumping power as compared to pure liquid to achieve equivalent heat transfer intensification,
- Reduced particle clogging as compared to convention slurries, thus promoting system miniaturization,
- Adjustable properties, including thermal conductivity and surface wet ability, by varying particle concentrations to suit different applications.

Preparation of Nanofluids

Nanofluids are a new class of fluids engineered by dispersing nanometer-sized materials (nanoparticles, nanofibers, nanotubes, nanowires, nanorods, nanosheet, or droplets) in base fluids(water, oil, ethylene glycol). In other words, nanofluids are nanoscale colloidal suspensions containing condensed Nanomaterials. They are two-phase systems with one phase (solid phase) in another (liquid phase). Nanofluids 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 [4].

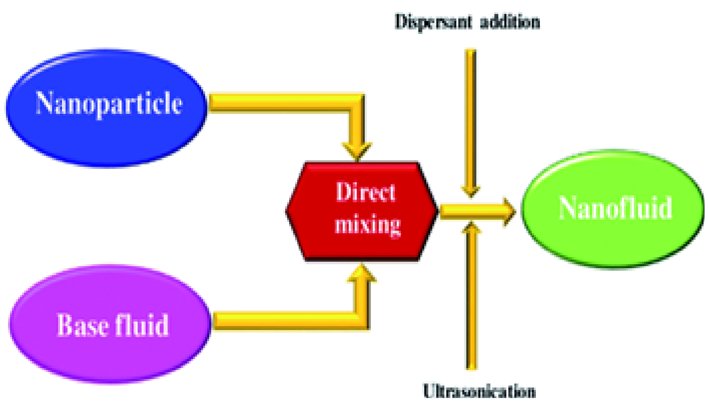


Fig.4 : Method of preparation of fluid

One Step Method

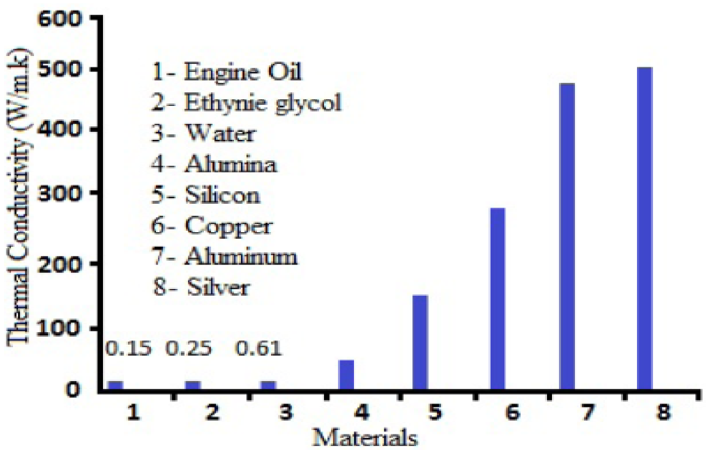
- The one step process consists of simultaneously making and dispersing the particles in the fluid.
- The vacuum SANSS (submerged arc nanoparticles synthesis system) is an efficient method to prepare nanofluids using different dielectric liquids.

Two Step Method

- In this method nanoparticle, nanofibers, nanotubes or other materials used are first produced as dry powders by chemical or physical methods [4].
- Then, the nanosized powder will be dispersed into a fluid in the second processing step with the help of intensive magnetic force agitation, ultrasonic agitation, high-shear mixing, homogenizing and ball milling.
- It is a most economical method.

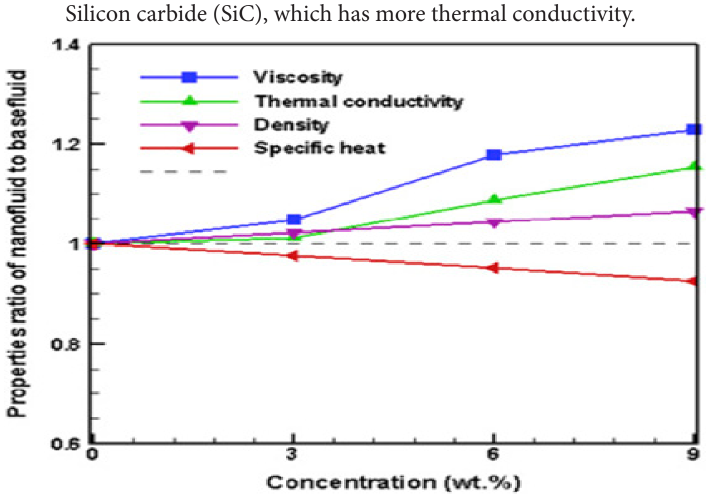
Thermal Conductivity of Nanofluids

- The thermal conductivity of nanofluids depends on many parameters like base fluids, volume fraction, particle size, temperature, surface charge, pH value, Brownian motion of nanoparticles, effect of clustering, nanolayer and dispersion techniques.
- The experimental data shows that K of nanofluid do not agree with the theoretical models results.
- The following graph shows thermal conductivity of some nanofluids [5].



Graph.1 Thermal conductivity of fluids

- From the above graph, silver and aluminium fluids will have the highest thermal conductivity.
- So we have chosen the nanofluids of Aluminium nitride (AlN) and Silicon carbide (SiC), which has more thermal conductivity.



Graph.2 Properties of fluids

Aluminium Nitride(Aln)

- Aluminum nitride (AlN)-Nanofluids is one of the typical ceramics that have special properties such as high thermal conductivity (8–10 times that of Al2O3), low dielectric coefficient (about 8.15), high electrical resistance, corrosion & erosion resistance and low density.
- Aluminum nitride nanoparticles (AlN) have been found to be a good additive for enhancing the thermal conductivity of traditional heat exchange fluids.
- At a volume fraction of 0.1, the thermal conductivity enhancement ratios are 38.71% and 40.2%, respectively, for ethylene glycol and propylene glycol as the base fluids [6].

Nano particle type	Base fluid	Synthesis process	Particle loading (%)	Particle size (nm)	Dispersion method	Stability
SiC	Water	Two step	9	40	Synthesis for 15mins + p^H of sol= 9.5	NR
AlN	EG	Two step	-	165	Stirred for 40 min @ 3000rpm	30h
AlN	Water	Two step	-	169	Sonication for 3h	NR

Table.1 Preparation steps for nanofluids

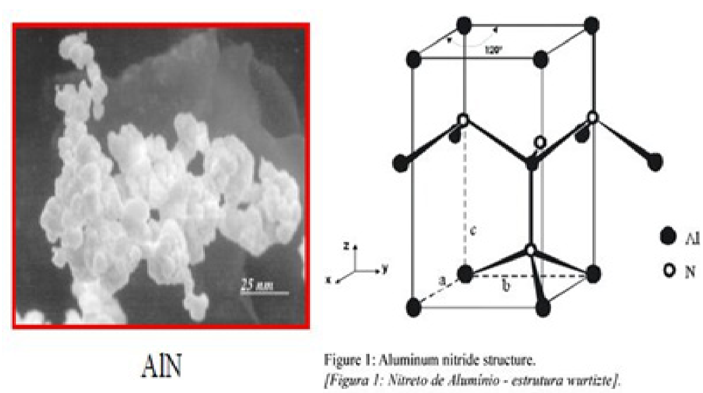


Fig.4: SEM view & structure of AlN

$Al(NO_3)_3 + 3H_2O$ Sunlight $Al(OH)_3 + 3HNO_3$

SILICON CARBIDE

The chemical formula of Silicon carbide is SiC.

- Silicon carbide (SiC) nanoparticles exhibit characteristics like high thermal conductivity, high stability, high purity, good wear resistance and a small thermal expansion co-efficient. These particles are also resistant to oxidation at high temperatures.

- It is hard substance as it is very difficult to break the corner lattice.

$SiC + 4H_2$ Sunlight $Si(OH)_4 + CH_4$

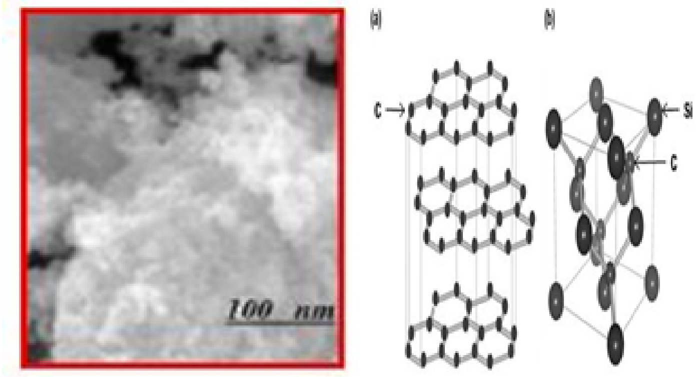


Fig.5: SEM view & structure of SiC

Description	Aluminium Nitride Nanofluid	Silicon Carbide Nanofluid
Compound formula	AlN	Sic
Molecular weight	40.99	40.1
Appearance	Off white	Gray powder
Melting point(°C)	2200	2730
Density(g/cm³)	2.9 – 3.3	3.0-3.2
Thermal expansion (µm/mk)	4.2-5.4	4.0-4.5
Thermal conductivity(w/mk)	80-200	120-170
Young's modulus(GPa)	330	370-490
Poison's ratio	0.21-0.31	0.15-0.21
Specification of heat (J/kg K)	780	670-1180
Purity (%)	99.5	99.1

Table 2- Specification of Nanomaterials

Material and Specifications

Material	Specification
 Copper tube	Nominal size: > 3/8inch Outer diameter (OD): > ½ inch (12.7mm) Inner diameter (K type)(ID): > 0.401 inch (10.211mm). Length of the tube: > 450mm
 Copper sheet	Thickness of the sheet: >0.10mm Dimension of plate: > 450x300mm
 Glass plate	Thickness of the sheet: > 2.4mm Dimension of plate: > 600x400 mm Dimension of Nano fluid glass: >300x250 mm
 MS Plate	Dimension of MS plate: > 600x400x100mm

Fig.6: Specification of materials

Thermocuple

A thermocouple is a device used extensively for measuring temperature. A thermocouple is comprised of at least two metals joined together to form two junctions. One is connected to the body whose temperature is to be measured; this is the hot or measuring junction. The other junction is connected to a body of known temperature; this is the cold or reference junction. Therefore the thermocouple measures unknown temperature of the body with reference to the Known temperature of the other body.

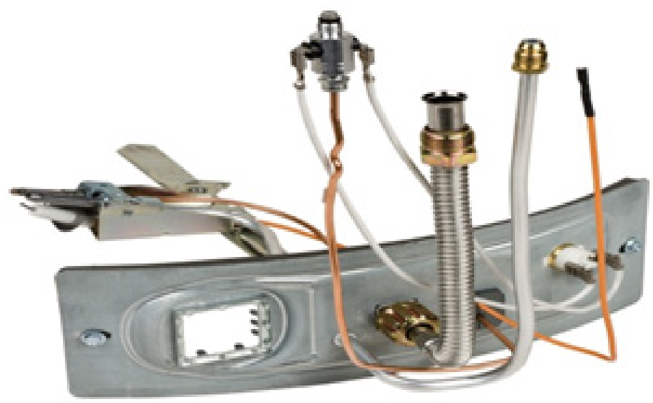


Fig.7: Thermocouple

Preparation of Aln & Sic Nanofluids

Fig 8: Ultrasonic Cleaner apparatus for sonicator process of AlN & SiC Nanofluids

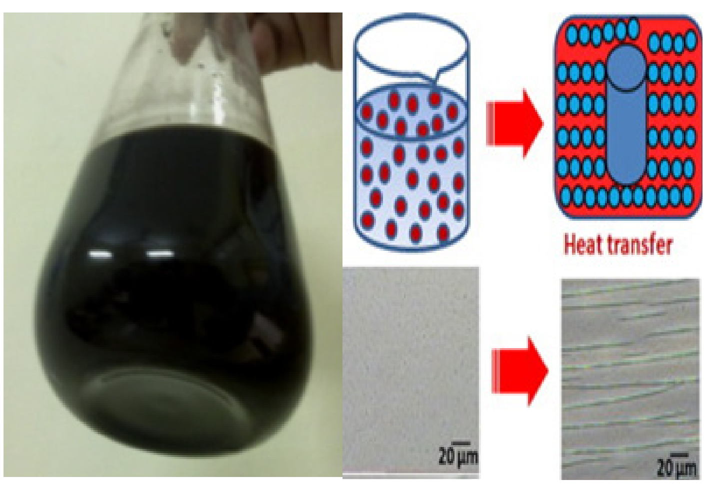


Fig 9: Ultrasonic mixer and prepared nanofluid solution

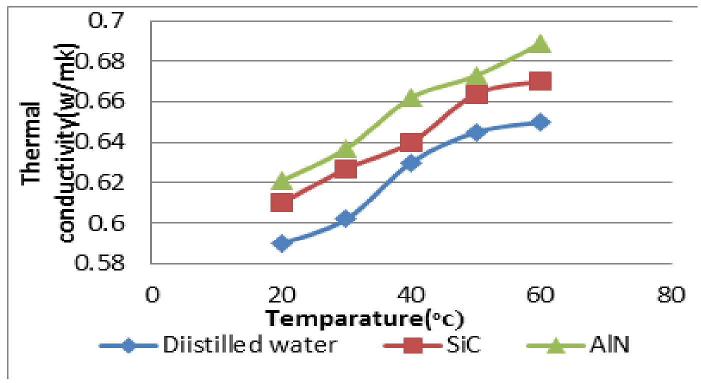
Thermal Conndructivity a And Efficiency of the Solutions

Early studies devoted for the determination of effective thermal conductivity of nanofluid are based on the classical analysis of Maxwell (1881) for two-phase solid–liquid mixtures given by:

$$K=[q/4\pi(T_2-T_1)]*[\theta_2/\theta_1]$$

T_2-T_1-Time period

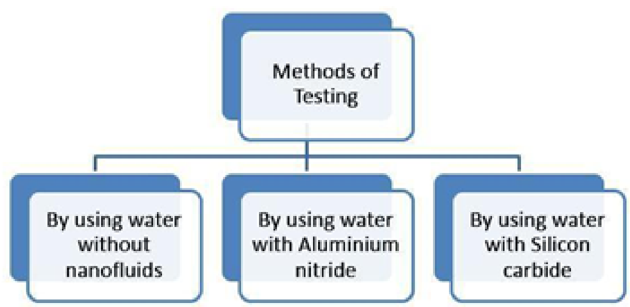
θ_2,θ_1 – temp at inlet & outlet condition



Graph.3 : Thermal conductivity of solutions

Methods 0f Testing

Separate Figure 1



Now a days, electrical consumption are very high. In order to rectify the consumption of electricity we use solar flat plate collector.

In general solar flat plate consists of copper tube, toughened glass, aluminium foil, black coated poly vinyl chloride copper sheet. The main working of this project defines that the Nano fluids which are additionally using in solar flat plate collector. The main objective of the Nanofluids is used in this project to improve thermal efficiency of the water. In this project we are using Aluminium Nitride (AlN) and Silicon carbide (SiC) Nanofluids which have more thermal conductivity while comparing to other. Here water is the base solution. The apparatus of the project consist of

- Solar flat plate collector
- Nanofluid arrangement
- Storage tank

From the water tank water is passed through the plastic tube to the Nanofluid arrangement .In Nano fluid arrangement which has copper tubes inside the arrangement and it is covered by a glass plate. The glass plate, which is used to absorb the heat energy and initialize the heating. By giving initialize heat to the Nano fluids to produce more heat. So we have taken the aluminium nitride and silicon carbide Nano fluids to improve the temperature of the water. Basically these two Nano fluids has more thermal conductivity.

Then the heated water is passed to the flat plate collector. Here flat plate collector having a parallel copper tube to increase the heat. And then we are using aluminium foil for reflecting purpose and then glass wool to withstand the heat and to control the heat not to affect by the surroundings.

In the copper tubes which is welded with black coated copper sheet, which is used to absorb the heat and also conduct the heat to the water, which is passing inside the copper tube. Flat plate collector, which is covered by the glass plate to absorb the heat. The outlet water (T2) which is measured by the Thermocouple. And the readings are noted and tabulated in the tabular column.

By Using Water Without Nano Fluids

In this method we are taking water in the Nanofluid arrangement. First the water is passed from the water tank into the Nano fluid arrangement through the tubes and the distilled water which is inside the Nanofluid arrangement and immersed the copper tubes. And the glass plate which is to cover the Nanofluid arrangement to absorb the heat and water get heated and also increase the heat in the copper tube. And the outlet heated water is passed to the flat plate collector and get more heated and the final outlet water is measured by the thermocouple.

By Using Water With Silicon Carbide

Nanofluids

In this method we are taking silicon carbide in the Nanofluid arrangement. First the water is passed from the water tank into the Nanofluid arrangement through the tubes and the silicon carbide which is inside the Nanofluid arrangement and immersed the copper tubes. The silicon carbide which has more thermal conductivity and the glass plate which is to cover the Nanofluid arrangement to absorb the heat and water get heated and also increase the heat in the copper tube. And the outlet heated water is passed to the flat plate collector and get more heated and the final outlet water is measured by the thermocouple.

By Using Water With Aluminium Nitride Nano Fluids

In this method we are taking aluminium nitride in the Nanofluid arrangement. First the water is passed from the water tank into the Nano fluid arrangement through the tubes and the aluminium nitride which is inside the Nano fluid arrangement and immersed the copper tubes. The aluminium nitride which has more thermal conductivity and the glass plate which is to cover the Nanofluid arrangement to absorb the heat and water get heated and also increase the heat in the copper tube. And the outlet heated water is passed to the flat plate collector and get more heated and the final outlet water is measured by the thermocouple.

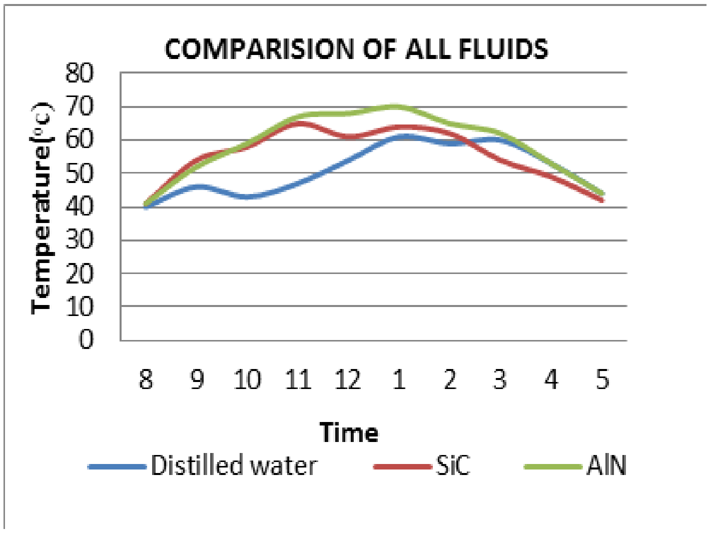
These three tests are taken in separate days and noted the reading and tabulated in the tabular column. And then by the graph we are comparing which has high thermal conductivity. And also by computation fluid dynamic analyze also obtained.

Tested Values

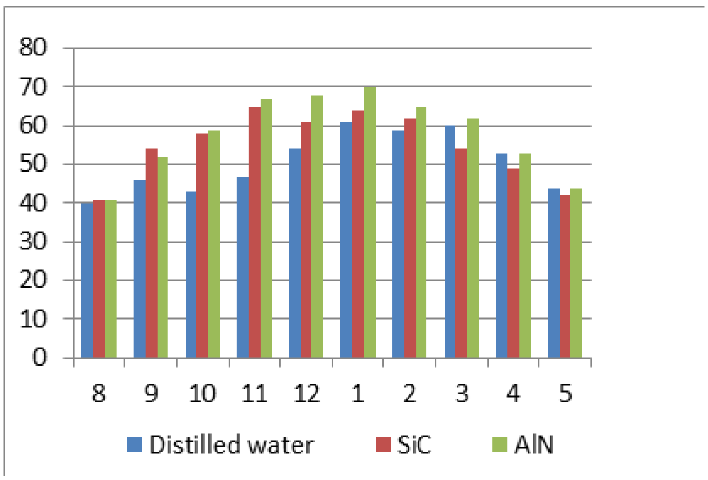
These three tests are taken in separate days and noted the reading and tabulated in the tabular column. And then by the graph we are comparing which has high thermal conductivity.

Time	Temperature of fluid(water)			
	at Inlet	at Outlet		
		Without Nano fluid	With SiC Nano fluid	With AlN Nano fluid
8 AM	39	40	41	41
9 AM	40	46	54	52
10 AM	41	43	58	59
11 AM	41	47	65	67
12 PM	41	54	61	68
1 PM	41	61	64	70
2 PM	41	59	62	65
3 PM	41	60	54	62
4 PM	40	53	49	53
5 PM	40	44	42	44

Table 3: Temperature value of all fluids



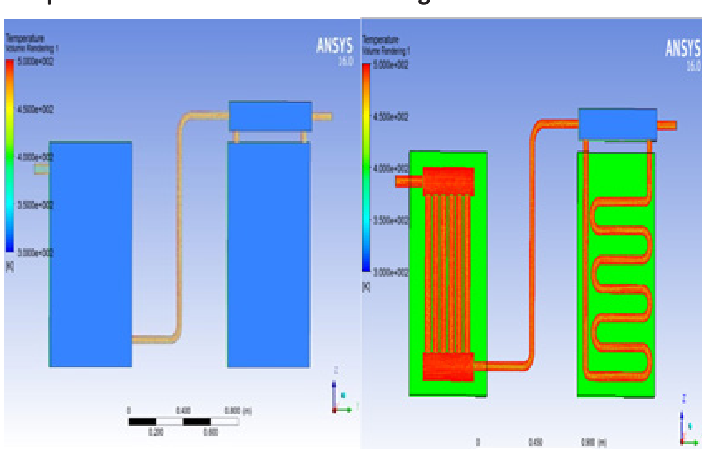
Graph 4: Efficiency of all fluid temperatures



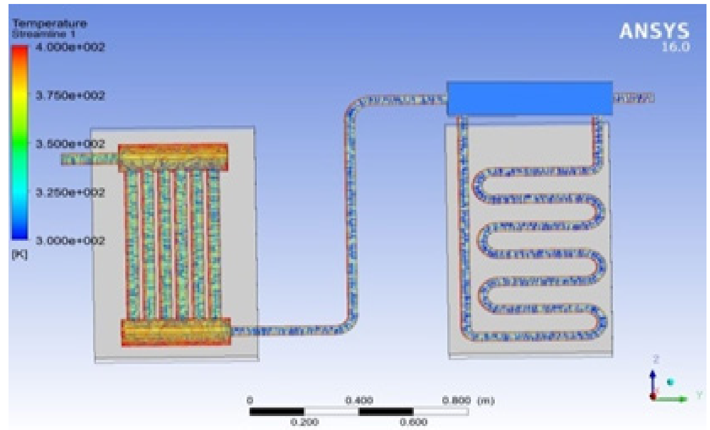
Graph 5: Bar chart for all fluids

Computational Fluid Dynamics (Cfd) Result

Temperature Flow of Fluid in an Arrangement



Velocity Flow of Solar Flat Plate Collector with Nanofluids



Experimental Setup

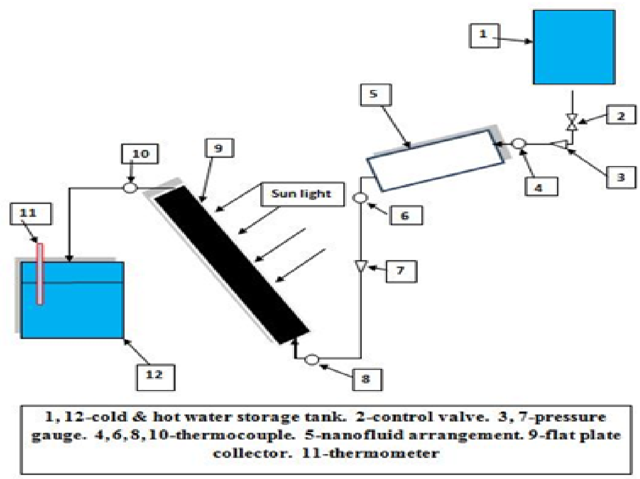


Fig 9: Experimental setup diagram

Fig 10: Photography

Result and Discussion

Comparisions

In project we have discussed about the flat plate collector and Nanofluids. And we compared the high thermal conductivity and high temperature in methods of testing. After the testing we conclude that the temperature difference in water, Aluminium nitride, silicon carbide. The graph and reading in tabular column denotes the temperature according to the date, time and fluids which are used.

While Comparing the Water

While comparing the water, the initial temperature (T1) which is maintained at the temperature of (39°c - 41°c). And the outlet temperature (T2) which has temperature rise and fall according to the climate condition. The maximum temperature in the range of (59°c – 61°c) at (1pm – 3pm). And all the readings are noted in the tabular column according to the time and weather condition.

While Comparing the Silicon Carbide

While comparing the silicon carbide, the initial temperature (T1) which is maintained at the temperature of (38°c - 41°c). And the outlet temperature (T2) which has temperature rise and fall according to the climate condition. The maximum temperature in the range of (61°c– 65°c) at (11pm –3pm). And all the readings are noted in the tabular column according to the time and weather condition.

While Comparing the Aluminium Nitride

While comparing the Aluminium nitride, the initial temperature (T1) which is maintained at the temperature of (38°c - 41°c). And the outlet temperature (T2)which has temperature rise and fall according to the climate condition. The maximum high temperature in the range of (62°c –70°c) at (11pm –3pm). And all the reading are noted in the tabular column according to the time and weather condition.

Conclusion

Based upon the fluids are used, we have conclude silicon carbide has high thermal conductivity and it temperature readings are high according to weather condition For the requirement of heating the water, we have choose aluminium nitride based upon the properties and thermal conductivity. If sometimes the temperature will differ due to climatic condition. But moreover it will give minimum temperature of 50°c.

Based upon the requirement of temperature fluids, were changed and which results in improve the heating and thermal efficiency.

Future Work

From the above chapters we have discussed about the Nanofluid arrangement and improving the efficiency.

The future work of the project is to make fins with copper tube on the Nano fluid arrangement and then make the copper tube as dual hollow section like internal and external tube.

The external tube with larger (diameter) consist of Nanofluids and internal tube with the water and the glass which is covered with the toughened (Teflon) glass gives more heat and it will improve and sustain thermal conductivity.

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