Comparative Analysis of Flat Plate Collector Performance using various Nanofluids

A Thesis Submitted

In partial fulfillment for the reward of the degree of

Master of technology

In Mechanical Engineering

SUBMITTED BY

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(2K19/THE/13)

UNDER THE GUIDANCE OF

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CANDIDATE’S DECLARATION

I, Umang Jain, here by certify that the work which is being presented in thesis entitled “Exergy and energy analysis of vortex Tube” being submitted by me is an authentic record of my own work carried out under the supervision of Prof Pushpendra Singh Department of Mechanical Engineering, Delhi Technological University Delhi.

The matter presented in this thesis has not been submitted in any other University/Institute for the award of M.Tech Degree.

Umang Jain

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CERTIFICATE

I, Umang Jain, hereby rectify that the work which is being presented in this thesis entitled "Exergy and energy analysis of vortex Tube" in the partial fulfillment of requirement for the reward of degree of Masters of Technology in Thermal Engineering submitted in the Department of Mechanical Engineering, Delhi Technological University Delhi is an authentic record of my own work carried out during a period from July2020 to June 2021, under the supervision of Prof. Pushpendra Singh, Department of Mechanical Engineering, Delhi Technological University Delhi.

The matter presented in this thesis has not been submitted in any other University/Institute for the award of M.Tech Degree.

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ABSTRACT

Solar energy is an infinite and enormous quantum of power. The quantity of solar radiation amounting to an enormous energy received by the Earth is much evolved and enhanced than the incumbent growth rate of commercial energy use on the planet. As a consequence, solar energy could sustain the demands to cater to the world's present and future energy needs on a unremitting basis. As a consequence, it has emerged as one of the most promising sources of alternative energy. In this research we have tried to evolve and proliferate the performance of solar flat plate collector by inducing nanoparticles in water and using them as working fluid. Energy and Exergy analysis has been performed at two different mass flow rate of 0.02 Kg/s and 0.05 Kg/s at different value of phi percentage ranging from 0.5 to 3 %. Cu nanoparticle has shown the greater effect on increasing the outlet temperature of working fluid for both mass flow rate while MgO has greater consequences on increasing coefficient of heat transfer.

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CHAPTER 1

INTRODUCTION

1.1. General

Solar energy is an infinite and enormous quantum of power. The quantity of solar energy intercepted by the Earth is about 1.8 1011 MW, which is much greater than the existing and incumbent rate of commercial utilization of energy existing on the planet. As a consequence, solar energy is much probable to garner the world's existing and upcoming energy reqirements and wants on a unremitting basis. As a consequence, it has emerged as one of the most promising sources of alternative energy. It is having advantage of its size, solar energy has two further advantages.

Humans and nature both work with energy, which is the most basic and universal kind of labour. The word energy is most often associated with input into their bodies or equipment, conjuring up images of crude fuels and electricity.

Fossil fuels are utilized to provide thermal power, and they are expected to be depleted in the not-too-distant future. As a result, non-conventional and renewable energy sources are required. And many nations make use of various types of energy. These energies include sun, wind, marine, geothermal, and biomass, all of which are abundant. These energies are both inexpensive and environmentally beneficial.

Solar power may be utilized as a primary source of energy. Among all the other energy sources, it has the most potential. Also, if just a tiny portion of it is utilized, it may have the highest potential. It is a type of energy that will become the primary source of energy after all other forms of energy have been exhausted.

Unlike fossil fuels and nuclear power, it is pioneer and an utmost ecologically friendly quantum of energy. Second, it is available in almost every nation where people live for free and in adequate quantities. However, there are many problems with its implementation. The most significant disadvantage is that it is a low-energy source. Solar radiation flow seldom exceeds 1 kWh/m2 even in the world's hottest locations, and daily total radiation is best at 6 kWh/m2. They are low numbers in terms of technological application. As a result, large collecting surfaces are required in many applications, resulting in excessive costs.

Solar energy supply fluctuates substantially over time and this is a second issue for its usage. Day-night cycles and the earth's orbit around the sun produce daily and seasonal variations in availability. Furthermore, due of local meteorological circumstances, variance occurs at a particular place. As a consequence, the energy collected in presence of sun shine must be collected for use when the sun does not shine. The system's cost is enormously evolved by the requirement of intermittent energy storage. As a consequence, overcoming these challenges is the real challenge of utilising solar energy as a quantum of energy. It is essential to strive toward the development of less costly gathering and storing methods in order to reduce the large upfront costs required in most applications.

flat plate collectors are a weatherproofed dish with approximately 800 pieces of convex mirror within.

1.2. Introduction

Fossil fuels account for the large amount of the world's energy production at the moment (80 percent). Mass consumption depletes these resources and presents a serious danger to the ecosystem, As a consequence, in particular, of global warming and water cycle degradation. The fossil fuels distribution on a worldwide scale is likewise unequal.

This leads to global economic instability, which has ramifications for the whole geopolitical system. In order to remain sustainable for more than two generations, the current structure must be changed. Without a doubt, it has a negative effect on the environment and on human beings. The greenhouse effect is the first and most important cause. The ability of the atmosphere to keep heat is influenced. The earth emits radiation at -18°C in the wavelength of a body as seen from space. Despite this, when gases are present, which are partially transparent to sun radiation and thus are open to infrared soil radiation, the average surface area is about 33°C hotter on average. This gas is very efficient in trapping heat between the surface of the earth and the center of the earth's atmosphere. CO2 (carbon dioxide) is a significant factor in this regard. It is inevitable that CO2 emissions from the burning of fossil fuels, especially coal, be released into the atmosphere. Remember that doubling CO2 concentration would result in an average temperature increase of 3 to 5°C. This is an important point to remember (estimated to 2035-2055). This corresponds to an increase in the coldest era of the previous ice age, which occurred between 18000 years ago and the current day. The effects of this kind of heating will be catastrophic for the human race. Sea levels are increasing in many areas of the globe as large sections of the polar ice caps melt and the ice caps melt more. Many ecosystems are destroyed because they are unable to adapt to the changing environment.

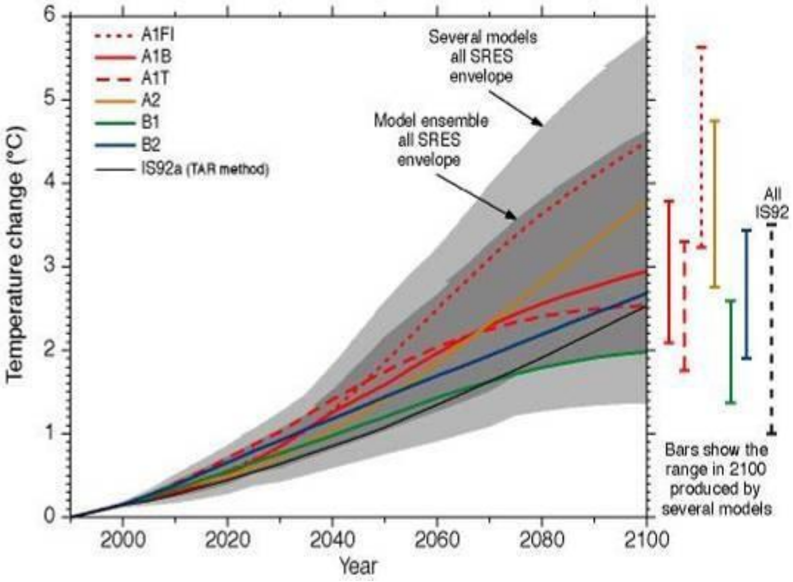


Figure 1.1: According to the IPCC study, temperature change is expected under a variety of emissions scenarios.

Traditionally used renewable energy sources are no longer hampered by their shortcomings. While these resources may be exploited, they are limited in their use due to a lack of knowledge of their origins and a costly initial investment in conversion technologies. Solar energy has tremendous promise as a source of renewable energy to fulfil the world's energy needs in the future. Everything that enters the earth's atmosphere has solar energy in the procedure of 1017 watts. Solar radiations may reach 1016 watts, which is 1000 times the amount of energy required by the whole world. The Earth has a power of 1016 watts. Using just 5 percent of the available energy will result in a 50-fold increase in global energy demand.

1.3 Global Market Overview

Renewable energy, which comprises conventional biomass, large hydro, and renewable energies, accounts for 19% of the world's total final energy usage (Small hydro, contemporary biomass, wind, sun, geothermal, and biofuels are all examples of renewable energy sources). Traditional biomass, which is mostly used to cook and heat, accounts for approximately 13 percent of this 19 percent, which is gradually decreasing or even disappearing in certain places as biomass becomes more efficient or more modern sources of energy are replaced. Hydroelectricity accounts for 3.2 percent of total power generation and is growing slowly but steadily. Other renewables account for 2.6 percent of the total and are rapidly growing in both developed and developing countries. [1]

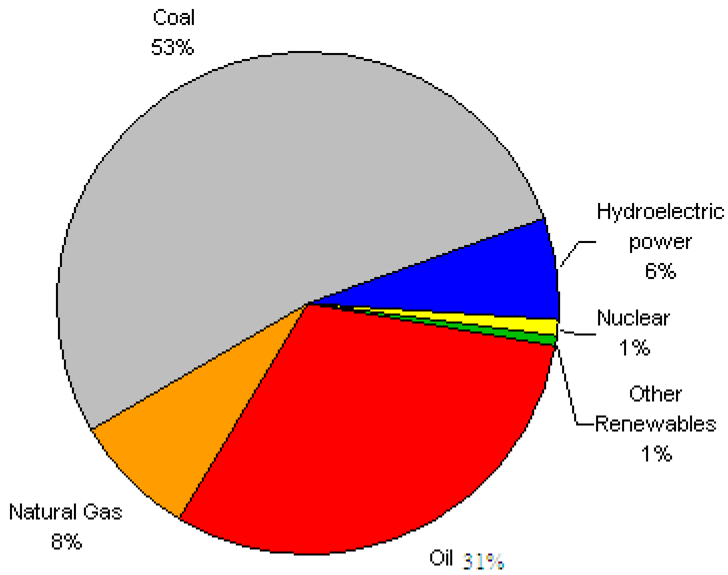


Fig1.2.- Energy consumption- In context of India [2]

Power production, warm water and space heating, transportation fuels, and rural (off-grid) energy services are all sectors where renewable energy is replacing traditional fuels. This section gives a summary of the first three markets' recent developments. During the five years from the end of 2004 to the end of 2009, global renewable energy volume increased at rates of 10–60 percent each year for various technologies. In 2009, growth increased for several renewable skills, such as wind power, compared to the preceding four yearsIn 2009, wind energy development outpaced the development of every other renewable energy source. When Renewable energies in the grid have grown, with a five-Year average annual growth rate of 60 percent, at the most high pace for photovoltaic (PV) technology any other renewable technology. Ethanol production grew by 20 percent on average every year while biodiesel production surged by 51 percent on average annually. (indicating lower production levels), although growth rates started to decline later in the decade.[3]

Other technologies, including as hydro, biomass and heat, and geothermal, are generally growing at a pace of 3-6 percent faster than fossil fuels (3-5 per cent, though in a number of developed nations). However, the development of these alternative renewable technologies in certain countries much outpaces the global average. [4]

1.4 Solar Energy

Almost all renewable energy sources are made completely of solar energy. The direct conversion of sunlight into electricity is known as photovoltaic solar energy conversion. Flat plate and concentrator devices may help with this. The photovoltaic effect, which involves the production of free electrons utilizing the energy of light particles, is a critical component of these systems. Electricity is generated using these electrons. [5]

Solar radiation may be found at every point on the Earth's surface. The highest irradiance of sunshine on Earth, regardless of location, is about 1,000 watts per square meter.

"In locations with a moderate climate, such as Western Europe, the ratio of diffuse annual insolation to total yearly insolation may vary from 10 percent in bright sunny spots to 60 percent or more in areas with a moderate climate. The kind of solar energy technology that may be utilized is mainly determined by the actual ratio".

Before reaching the earth's surface, The absorption, reflection, and transmission of sunlight are all affected by atmospheric processes. Solar radiation is the world's most numerous and consistent energy source.

On an hourly basis, the quantity of solar energy absorbed by the earth's surface outpaces the total amount of energy used by the whole world's population in a year. Due to the fact that solar energy may be utilized for as long as the sun shines, it is sometimes referred to as renewable or sustainable energy. The primary stage of the sun is expected to last another 4–5 billion years, according to estimates. Insulation is the term for the energy emitted by the sun, known as electromagnetic radiation.[6]

Solar energy may be turned into electrical energy in two different ways:

1. SOLAR THERMAL PLANT
2. SOLAR PHOTOVOLTAIC

1.5 Solar Concentrators

1.5.1 Introduction

Solar concentrators are devices that gather light and increase it above the flux at the entry aperture on the absorber surface, thus increasing the amount of energy collected. In order to achieve optical concentration, incident flux must be focused onto a suitable absorber using either reflecting or refracting components. Because of the apparent diurnal motion of the sun, If both the concentrate surface and the absorber stay stationary, the concentrated region, whether reflecting or refractive, will be unable to re-focus solar power on the absorber at all levels of the solar spectrum. The apparent movement of the sun should be closely monitored by all of the components, including the mirror/lens and the sensor, to ensure that all of the absorbers are exposed to sunlight at any given moment. Many people have already shown interest in solar collectors for heating pool water, which may be built using simple materials. Collectors of sunlight are often classified into two groups: intent and non-concentrating. In concentrating type collectors, the total solar energy impinge on the collecting surface is usually focused by employing parabolic/concave mirrors/reflectors to growth the efficiency of the accumulator. A huge collector surface is usually achieved as a consequence, and the temperature attained is very high. A broad range of uses for non-concentrating collectors, such as those used to heat pool water, may be found in a number of industries. Non-concentrated collectors such as flat plate collectors and evacuated tube collectors are the most frequent types of collectors. Flat plate collectors are the most often used kind of collector since they are easy to build and need little maintenance after installation. Despite the fact that evacuated tube collectors are a relatively recent technology, they are excellent for use in regions where there is little sunshine or when the ambient temperature is low. [7]

Flat plate solar collectors are heated pool water over a wide surface and are suitable for use in places like India, where sunlight is abundant throughout the year and flat plate solar collectors are inexpensive. The fact that flat plate solar collectors have substantial heat losses has not stopped research into how to build better flat plate solar collectors that surpass evacuated tube collectors.

Our hybrid solar collector, which we developed and constructed, has flat plate collecting technology as well as concentrated type collector technology. Testing was performed on the collector when it was unglazed (i.e., without a glass covering), and the results were found to be in agreement with expectations.

As a result, a solar concentrator is made up of the following components.

- A solar tracking system that is always on.
- A concentrating expedient
- A black metal absorber with a transparent cover.

Solar concentrators may reach temperatures of up to 3000 degrees Celsius and can be used in both photo thermal and photo voltaic solar energy conversion.

A solar collector is a device that gathers solar energy and transfers it to a contacting fluid. Solar collectors are required for exploitation of solar energy. There are two types of people in general:

- Non-concentrating
- Concentrating type

1.5.2 Solar Collector

- **Non-Concentrating collector**

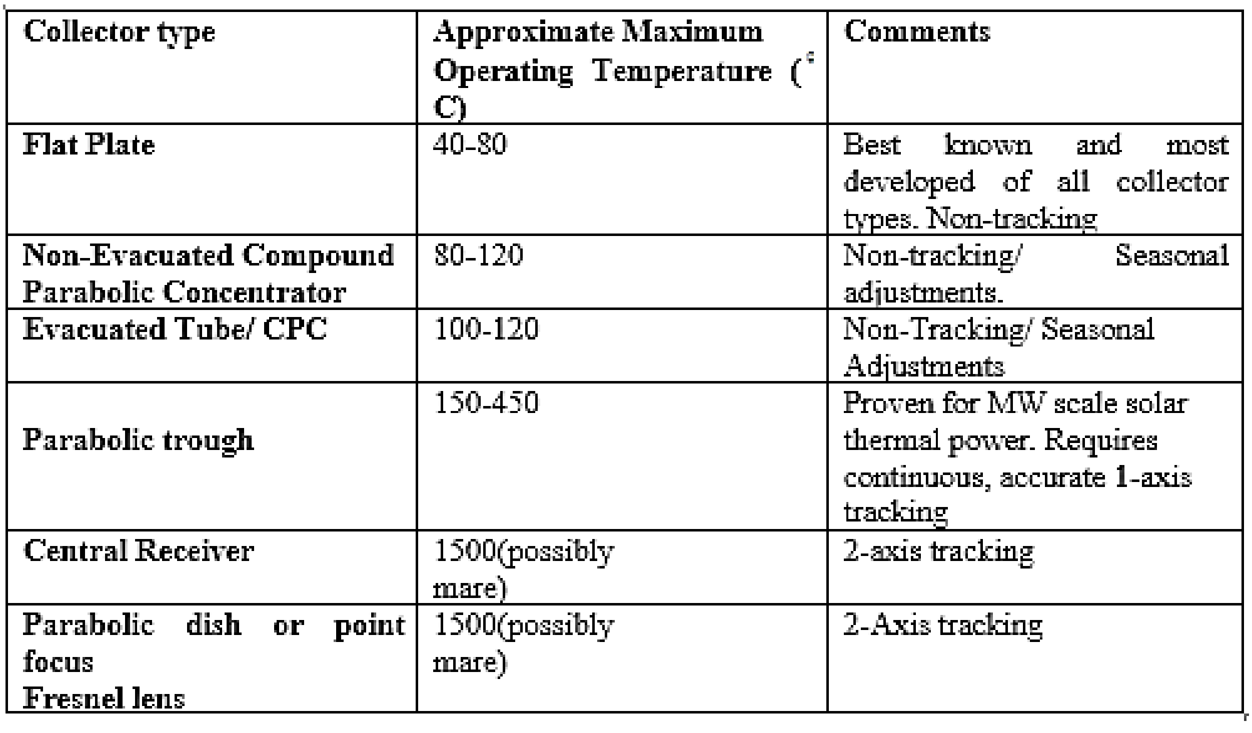
(a) Flat plate collectors

Flat panel collectors are frequently used in both residential and commercial buildings to heat water or to provide space heating, among other things. The temperature at which the machine operates is typically between 40 and 80 degrees Celsius.

There are many kinds of solar collectors, but this is the most well-known. It has a relatively simple design that comprises the absorber plate, the tubes sold to the absorber plate, an isolated frame, and transparent glass. It is also possible that the absorber plates will be coated with a selective coater that has a high solar absorption but low thermal emission, in order to maximize solar gain while minimizing radiational losses, on occasion. You are not required to keep track of your progress. Depending on the application, the tubing soldered to the absorber plate either transmits the heated medium or a heat transfer fluid to transfer the heat into the heat exchanger, if the heat has been transferred to a suitable medium via the absorber plate. The use of indirect heating prevents the formation of scaling and tube blockage. The absorption of both direct and diffuse solar radiation is a significant advantage of flat plate collectors, and this is one of its primary advantages. This means that the collector will continue to operate even if the sky is cloudy and diffuse radiation accounts for almost all of the available light.[7]

Fig. 1.3: Typical Flat plate collector.

Table: 1.1 Collector overview and operating temperature ranges



Collector type	**Approximate Maximum Operating Temperature (° C)**	**Comments**
Flat Plate	40-80	Best known and most developed of all collector types. Non-tracking
Non-Evacuated Compound Parabolic Concentrator	80-120	Non-tracking/ Seasonal adjustments.
Evacuated Tube/ CPC	100-120	Non-Tracking/ Seasonal Adjustments
Parabolic trough	150-450	Proven for MW scale solar thermal power. Requires continuous, accurate 1-axis tracking
Central Receiver	1500(possibly mare)	2-axis tracking
Parabolic dish or point focus **Fresnel lens**	1500(possibly mare)	2-Axis tracking

- **Glazed flat-plate collectors**

A common collector type is flak glazed collectors, which are available in both liquid and gaseous versions. They are better suited for applications with demand temperatures ranging from 30 to 70 degrees Celsius, as well as for heating applications during the colder seasons. The most frequent use for liquid collectors is the heating of hot water in residences and businesses, as well as in structures and indoor swimming pools, among other things. Using air collectors, crops are heated, aired, and dried in order to maximize yield.

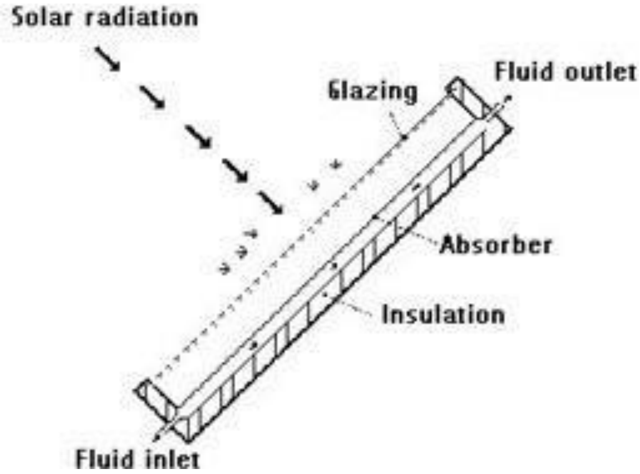


Fig. 1.4 Glazed flat-plate collector [7]

- **Unglazed flat-plate solar collectors**

The lack of insulation makes these collectors particularly well suited for applications where the temperature requirement is less than 30 degrees Celsius. This kind of collector has commercial water heating potential in seasonal locations such as summer camps that are separated from the rest of the world.

Fig.-1.5 unglazed flat-plate collectors [6]

Flat plate collectors without glazed typically are constructed from black plastic coated with a UV stabilizer in order to avoid fading. These collectors absorb a larger proportion of the sun's energy since there is no glass covering them.

- **Unglazed perforated plate collectors**

An industrial quality side or envelope with several tiny pitches of 2-4 cm is essential for this type of collector. Before being sent to the structure, the air passes through the collector's aperture to deliver warm, fresh ventilation air. Typically, since the collector functions at a temperature that is close to that of the surrounding air, its efficiency is good. The fact that only additional costs must be weighed against the energy savings suggests that Such systems may be very cost-effective, in particular when utilized for replacing the traditional construction cladding. The most frequent application is to heat the air circulating through a ventilation system in the building.

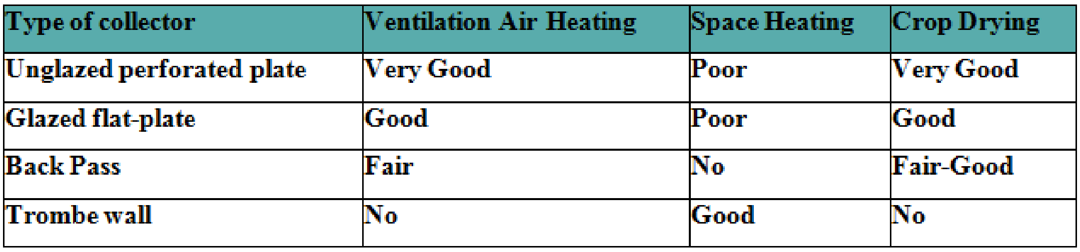
- **Back-pass solar collectors**

Solar energy is utilized to heat air in air-based collectors. Due to the absence of pressure piping, They have a simple form and are usually lighter than fluid collectors. Freezing or boiling do not harm the air collectors. A huge solar absorber is utilised in these systems to heat the air. One-pass open collectors are the simplest designs. Glass collectors can also be used in space to heat air. These varieties of collector can be employed with the thermal weight of a dwelling. [9]

- **Air based solar collectors**-

Air-based solar accumulators gather energy that may be utilized for ventilation, room heating, and crop drying. In Canada, ventilation air heating is the most frequent use. There are three kinds of air-based collectors, each of which is suitable for one of three uses-

Table: 1.2 Collectors and their assets- [9]



Type of collector	Ventilation Air Heating	Space Heating	Crop Drying
Unglazed perforated plate	Very Good	Poor	Very Good
Glazed flat-plate	Good	Poor	Good
Back Pass	Fair	No	Fair-Good
Trombe wall	No	Good	No

Basic projects are the initial three types of collectors. Because the pipework is not pressurized, the collector usually weights less than the collector on a liquid basis. Air-based collectors also have the advantage of not being affected by freezing or boiling.

- **Batch solar collectors-**

A century ago, black-painted water tanks were utilized as basic solar water warmers for the domestic water. Residential water heating in warm climates is currently the company's most important market. During the winter, either the tanks must be threatened against freezing or they must be flattened. In contemporary batch collectors, a reflector and/or glass, similar to those used on flat plate collectors, are utilized to direct solar radiation onto the tank surface, thus increasing efficiency. Due to the fact that the storage tank and solar absorber are integrated into a unique mono device, extra components are not needed.

- **Liquid-based solar collectors**

Sunlight heats a liquid that circulates in a "solar loop" in liquid-based collectors. Water, antifreeze mixtures, thermal oil, and other fluids may be used in the solar loop. The collector's thermal energy is transmitted via a solar loop to a thermal storage tank. The kind of collector you'll need is determined by the temperature of the water and the environment in your area. Liquid-based solar collectors are the most popular

- **Concentrating solar collectors**

The size of a solar collector's absorber may be significantly decreased by employing reflectors to focus sunlight on it, which lowers heat losses and improves efficiency at high temperatures. A fluid, air, or even an oven, such as a solar cooker, may be used, are all examples of stationary concentrating collectors. Concentrating collectors are divided into four categories:

  - Parabolic trough
  - Parabolic dish
  - Power tower
  - Stationary concentrating collectors

- **Parabolic dish systems**

A parabolic plaster collector is comparable to a big satellite platform in that it includes reflectors, such as a mirror, and a central absorber. It is equipped with a two-axis sun tracker. In the center of the plate, a parabolic plate system with a computer monitors the sun's rays and focuses them on the receiver using a parabolic plate system. In certain configurations, a heat engine that generates heat electrically, such as a Sterling engine, is connected to the receiver. In the modest power range, parabolic plates may achieve temperatures of up to 1000°C and can convert solar energy into electrical energy at the receiver.

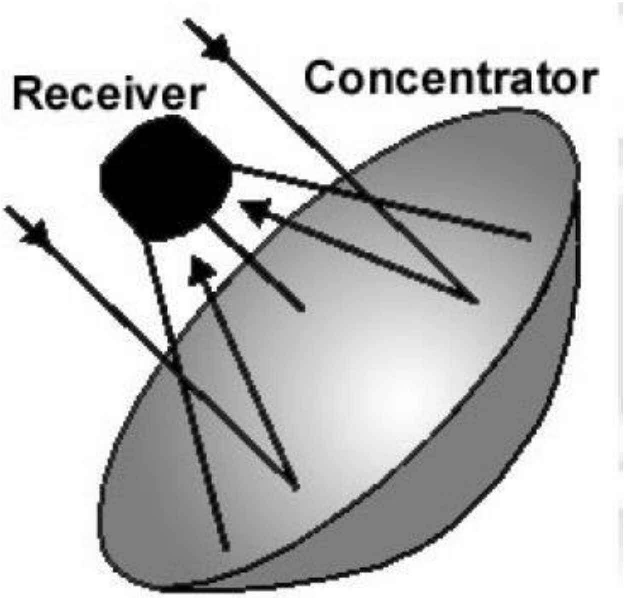


Figure:-1.6 Parabolic dish

- **Parabolic trough system**

Devices shaped similar the letter "u" are known as parabolic troughs. The troughs focus sunlight onto a receiver tube that runs parallel to the trough's focal line. To minimize heat loss, the receiver tube is often encased in a clear glass tube. Single-axis or dual-axis tracking is often used in parabolic troughs. They may be inactive in certain cases. Temperatures in the receiver may exceed 400 degrees Celsius, producing steam that is used to generate power.

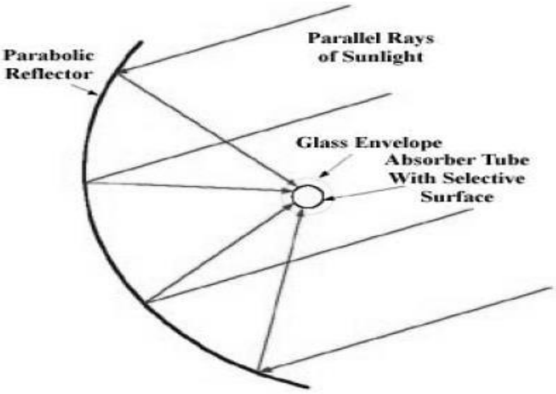


Fig:-1.7 Parabolic troughs

- **Power Tower System-**

A heliostat is a type of solar power concentrator which transmits solar energy through a field of dual axis sun trackers to an enormous absorber. mounted atop a tall structure. To far, the heliostat collector has only been used to generate electricity in a configuration recognized as the power tower. Throughout a power tower, an array of massive mirrors tracks the path of the sun across the sky.

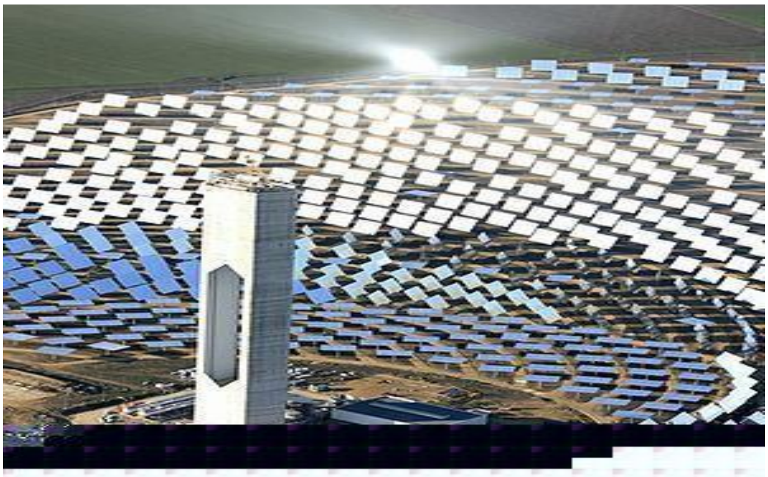


Fig.-1.8 Power tower system

- **Stationary concentrating solar collectors**

Solar energy is transferred to a neighboring absorber or aperture via a broad acceptance angle when fixed concentrate collectors with flat reflectors and compounds are employed, which is achieved through the use of compound parabolic and flat reflectors. Because of their wide acceptance angle, these reflectors do not need the use of a sun tracker. Flat flooring collectors, flat flooring collectors with parabolic boosting mirrors, and flat flooring collectors with sun heating are all examples of solar energy systems that fit under this classification. Solar cookers are widely used in developing and developing countries alike.

Fig:-1.9 Stationary concentrating solar collectors

- **Vacuum tube solar collectors**

Solar collectors that make use of vacuum tubes (also known as "evacuated" tubes) are among the most efficient and expensive kinds of solar collectors currently available, notwithstanding their high efficiency. They are especially well-suited for applications with demand temperatures ranging from 50 to 95 degrees Celsius and/or for very cold conditions, such as those found in Canada's far northern hemisphere. Another potential use is for cooling buildings via the renewal of refrigeration cycles, It is possible because of its ability to effectively transport high temperatures. [10]

- **Central Receiver System**

On the right side of the figure, you can see the center receiver, encircled by field heliostats (2 axial flat mirrors that are independent of movement). It is possible to reach temperatures of up to 1500 degrees Celsius. The recipient is normally composed of bent tubes containing heat fluid and molten salt to store energy in the form of latent thermal energy.

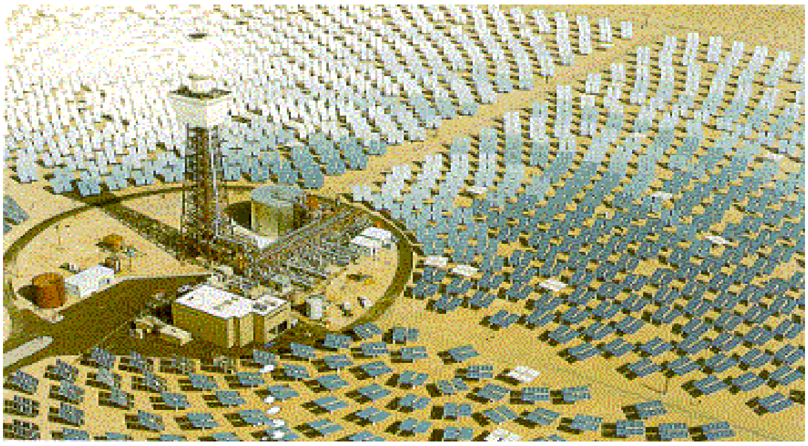


Fig:- 1.10 A Central Receiver solar power plant

- **Evacuated tube solar collector**

Heat pipe tubes constructed of evacuated glass tubes with an absorber plate fused to a heat pipe are known as evacuated glass tube heat pipe tubes (EHPTs). The manifold is insulated and placed in a sheet metal or plastic container to keep it protected from the weather during transportation. In comparison to flat-plate collectors, the vacuum around the tube's surface minimises heat loss to the outside via convection and conduction, resulting in higher efficiency than flat-plate collectors, particularly at lower temperatures. Generally speaking, this benefit is lost in hotter regions, especially when very hot water is needed, such as industrial process water. To avoid overheating, the high temperatures that may develop may need specific system design. [11]

Fig:-1.11 Evacuated tube solar collector

An evacuated upper end tube (glass-metal) contains one coating of glass that is fused to the hot tube, and the thermal tube and the absorber are fully vaccinated. While the absorber and the heat pipe are maintained at a normal air pressure, others (glass-glass) have a dual layer of glass fused with a vacuum between layers at either end of the pipe (similar to a vacuum bottle or flask). In comparison with other kinds of vacuum tubes, glass-glass tubes feature a vacuum seal which is very reliable. The two layers of glass, however, restrict the amount of light the absorber may reach in operation. Moisture may enter the tube via the non-evacuated area, resulting in corrosion of the absorber's internal components. While the compositions of glass-metal tubes vary, they both allow lighter to reach the absorber while also protecting both the absorber and the heat pipe from corrosion.[11]

1.6. Applications of solar collectors

- Government hospitals, hospitals, and nursing homes are all included.
- Hotels, motels, and banquet facilities
- Barracks in a prison, bars in a jail, bars in a jail, bars in a jail, bars in a jail
- The Punjab Urban Development Administration and Group Housing Societies have developed housing complexes.
- All residential buildings built on a 500 square meter plot are subject to the jurisdiction of the municipal/corporate and urban development authorities in Punjab.
- All public buildings, residential schools, schools, hostels, institutes of vocational training, district educational institutes, resorts and universities, etc.
- According to Punjab Energy Development Agency, solar water heaters in Punjab state are 16 lake capacity (PEDA).

1.7. Project Objective

There are three main objectives that must be achieved:

- A new technique to making flat plate solar collector system selection simple.
- A method for evaluating the various systems and determining which is the best.
- Sensitivity analysis for determining a more effective parameter for system selection.

1.8. Organization of Thesis

This thesis is split into five following chapters

CHAPTER-1

This chapter describes the aims and objectives of the research topic, as well as the demand for cheaper, long sustainable solar water heater applications and the study's findings .

CHAPTER-2

This chapter comprises literature review, reviews the work that has been already completed in the field of solar collector and Solar heating system.

CHAPTER-3

This chapter consist the Methodology of experimental investigation of the analysis to investigate properties of solar radiation in solar collector.

CHAPTER-4

This chapter demonstrates the modelling and design Solar collector model analysis utilizing various NCH approaches. This chapter contains an examination of the findings and comments on the evolved rate of heat transfer of developed solar collector models.

CHAPTER-5

The conclusion includes the pinpoint the results of this investigative study as well as future prospects.

CHAPTER 2

LITERATURE REVIEW

2.1. Literature Review

This chapter gives the study of the FPC and the PVT collectors a critical overview. An overview of the FPC- and PVT-related application literature in cooling systems. Several study and testing of nanofluids as fluids have found that nanofluids have a greater thermal conductivity than conventional fluids, indicating a better capacity to effectively transmit thermal fluids. Academics have done extensive exercise on the calculation of thermal performance in solar water heating systems. A significant number of scholarly papers based on their results have been published. Researchers utilized a variety of manufacturing methods to better understand the characteristics of nanofluids and predict their thermophysical properties.

Bahaa Saleh et. al. (2021) The thermophysical properties of the fluid have improved in reaction to the hybrid nanofluids, and the thermal efficiency of the heat collector has significantly increased. Compared with the results obtained by water, the highest increases were found in thermal conductance and viscosity at 0.3% volume and 60° Celsius of 28.46% and 50.4% respectively, as compared to the values obtained by water.At 0,3 percent and 60 degrees Celsius, the volume of the concentration increases is 18,68 percent, 39,22 percent, and 18,91 percent, respectively, above the water figure, with the constant of heat transfer and friction factor at maximum sun exposure. When compared to water data, the heat collection efficiency increased by 28.9 percent in 13:00 hs sunshine, by 0.3 volume percent, and by 1413 Reynolds. A relationship between the friction factor and the number of Nusselt has been discovered via empirical investigation.

Qudama Al-Yasiri et. al. (2021) It summarized current research on increasing the thermal efficiency of FPSCs by using the most important influencing factors, such as particle concentration, particle size, and collecting field, as well as other variables that have been identified. Non-profit organizations (NFs) are organizations that are not for profit (single and hybrid NFs). Once this is done, the most important barriers that researchers have reported on are highlighted (for example: instability; viscosity; concentration limit; corrosion impact, and so on), and it is regarded to be helpful for novices in this field to know about them. Following the findings of the research discussed here, NFs may be able to significantly enhance the energy and exercise efficiency of FPSCs even at low concentrations. This article addresses the usage of nanofluids in FPSCs to advance the overall thermal presentation of the device. It is briefly addressed the properties of nanofluids, including their categorization and production techniques, as well as their thermal performance in FPSC. It is also addressed in terms of the major roadblocks to its use and promotion.

Eric C. Okonkwo et. al. (2020) A correlating carefully developed model for their thermal conductivity, specific heat, and viscosity was constructed by testing the thermal properties of the two nanofluids across a variety of temperature ranges and comparing the results. For both the first and second laws of the collector, a thermal model of the FPC was built using the engineering equation solver and used to evaluate the collector. In the next step, the system was subjected to parametric analysis and optimization, which included testing it at different temperatures, volumetric percentages of nanoparticles, and mass flow rates under various conditions. The results indicate that using 0.1 percent alumina water evolved thermal efficiency of the collector by 2.16 percent, while utilizing hybrids resulted in a 1.79 percent reduction in thermal efficiency as compared to water, according to the researchers. Hybrid nanofluids are a kind of nanofluid that combines the properties of two or more fluids. While hybrid nanofluids were shown to be no more efficient in transferring heat than water, they did provide a 6.9 percent improvement in exergetic efficiency when compared to the alumina-water nanofluids, which provided a 5.7 percent gain in efficiency.

Faisal Amir et. al. (2019) In this investigation, a solar collector model was created and solved using an equation solver engineering software, which was used to conduct the research (EES). The method is used to determine the surface temperature, which allows the heat energy contained inside the collector to be used to its full potential. The simulated solar collector measures 1 m × 2 m x 0.06 m; the aluminum and zinc plate absorbers are 0.04 mm and 0.06 mm thick, respectively, and are claimed to have been plate absorbers. Because the aluminum absorber weighs much more than the zinc plate used as the absorbent plate, the simulation results showed that a liquid out temperature was reached using this material. The fluid out of fluid temperature with 0.4 mm aluminum plates is higher than the fluid out of fluid temperature with a 0.6 mm platform size. The temperature of fluid discharged through a copper tube is higher than the temperature of fluid discharged through a flat-platform copper tube metal tube having a higher heat rating than the tube When the simulation findings are compared to the test results, The fluid out temperature obtained by the test findings is lower than the fluid out temperature produced by the modelling results using the collecting pipes.

M.E. Zayeda et. al. (2019) Within FPSCs, this research looks into the sequence studies of metals and metal oxides as well as crystalized half-conductor oxides and carbon-based nanofluid (HTF) in order to understand how they interact. FPSC thermal performance is greatly influenced by many factors, including nano-articles, nanoparticles, nanoparticles, and the mass nano fluid flow rates, all of which have been thoroughly studied in the current study. Under the same operating circumstances, the researchers will investigate different kinds of only FPSC-used nanofluids or hybrid nanofluids. Under the same procedure circumstances as carbon-based nanofluids, the results of this study show that FPSC has much better energy and exergy efficiency than metal oxide nanofluids, according to the findings. Copper oxyhydroxides It is discovered that nanofluid metal oxides perform better in comparison to conventional fluids because they increase efficiency in the concentration range of 0.025 percent to 20 percent and In comparison to typical fluids, the mass flow range ranged from 1,0 to 8,8 kg/min by 6,3 to 37,3 to 5. A comprehensive and comparative approach is taken for each kind of nanostructure, and it includes notable findings, proportions, and upcoming predictions for each type of nanostructure.

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Naveed Akram et. al. (2019) This research examined the impact of nanofluids from the clove-treated nanoplatelet on the efficiency of the flat-solar collector. Graphene nanoplatelets and clove buds were all mixed in a single pot method to achieve this purpose. The potential Zeta test was used to evaluate graphene nanofluid stability, and it was shown to be highly stable after 45 days. Following that, a synthesis of three different mass levels was performed: 0,025 percent mass, 0,075 percent mass, and 0.1% mass. The thermal efficiency of the solar flat plate collector was investigated in the following phase at three different nanofluid concentrations and three different mass flow rates, 0.0133, 0.0200, and.0260 Kgs s-1 m-2. The results revealed that the solar collector's thermal performance Improves the increase of mass and mass flow rates, but decreases as temperature drops. The solar collector's maximum temperature performance was 78 percent at a mass concentration of 0.1 mass percent and a flow rate of 0.0260 kg s-1 m-2, which is 18,2 percent higher than water under equal flow situations.

Shubham Sharma et. al. (2019) Emphasis was placed on the function of CeO2/water nano-fluid in determining the energy and capability of flat plate solar collectors throughout the study process. As a result of our experimental results on changing mass flow rates, we concentrate on a broad range of concentrations in order to get the best thermal performance possible for the smallest possible volume concentration. There has been a substantial improvement in the thermal conductivity of this O2/water nanofluid, and the dynamic viscosity has been reduced somewhat (41.7 percent at 1.5 percent voltage concentration). The first legislation's analysis is used to amount the working of flat-plate collectors, while the second legislation's studies are used to evaluate the value of energy flowing through the collectors. Experiments have shown that utilizing water as a base fluid resulted in the highest collector efficiency of up to 57.1 percent at a concentration of 1.0 percent particle volume at a flow rate of 0.03 kg/s when using a concentration of 1.0 percent particle volume. At an optimal concentration of nanofluid and a flow velocity of 0.01 kg/s, exergetic efficiency was found to be 84.6 percent (1.0 percent particle volume) at an exergetic efficiency of 84.6 percent (1.0 percent particle volume).

Wisam J. Khudhayer et. al. (2018) The FPSC efficiency was assessed on the basis of the impact on the temperature differential between fluid input and output and FPSC thermal efficiency of the fluid type with a constant rate of fluid flow (1.5 litre) and constant nanoparticular (0.1 per cent) volume concentration of nano-fluids. Due to its increasing thermal conductivity, the CuO/water nanofluid utilised in FPSC as the working liquid transmitted heat more quickly than the nanofluid TiO2/water and the basic fluid used as working fluid (water). For water, CuO and water and TiO2/water nanofluids, the inlet-outlet temperature differential was 6.6 degrees Celsius, 7.1 degrees Celsius and 7.9 degrees Celsius at 1.5 degrees/month. . The greatest efficiency was found to be 55 percent for the cuo/water Nanofluid, compared to 54 percent and 0.1 percent for the TiO2/water and water, respectively; the best efficiency was found to be 55 percent. Empirical correlations were created using raw experimental data on the base fluid (water), the CuO/water nanofluid, and the Tio2/water nanofluid, which were entered into a statistical computer software programme and analyzed. (Nusselt number as a Reynolds and Prantal number Nusselt).

Dharmalingam R et. al. (2017) Experiments on the performance and use of copper oxide Nanofluids are being conducted in solar flat plate collectors. The study's objective is enhance the performance of the collector by incorporating nanofluid. Nanoparticles of copper oxide are combined with water to form a solution. The mixture is utilized to absorb the greatest amount of solar radiation in order to maximize the effectiveness of a flat solar plate collector used as a working medium. Copper oxide nanoparticles are used in this application because of their high heat conductivity. There are many use for this device, including monitoring the working medium outlet temperature and pressure drop, comparing and evaluating the efficacy of a solar plate collector, and determining the thermal conductivity of nano-flow and water. As copper oxide nanofluid is used as the work medium at mass flow rates of 0,016, 0,033, and 0,05 kg/s, the efficiency of the solar gatherers is improved by 36 percent, 38 percent, and 39 percent, respectively, when compared to the control group. The findings have shown that copper oxide nanofluid is a suitable material for improving the function of of solar flat plate collectors.

Francesco Calise et. al. (2017) A Photovoltaic/Thermal Solar Unglazed (PVT) collector model was developed using a single-dimension finite-volume approach. In this setup, a standard solar PV collector is connected to an appropriate heat exchanger through a heat pipe. The collector, in particular, is equipped with a rolling bond heat exchanger and does not have an insulating back and frame, as would be expected. The flow direction of the generative collector is distinct in the longitudinal direction when seen from above. Mass and energy balance are implemented for each finite volume element of the discretized computer domain, and this is done for each discrete volume element. The shape and material characteristics of the collector were derived from a commercially available device. An experimental on-site study is carried out in order to validate the proposed model. This model is used in certain circumstances to evaluate the electric and thermodynamic properties of individual domain elements. A sensitivity analysis is performed to evaluate the excellent actions of the generative collector in respect to the major concepts and environmental factors involved.

Ehsan Shojaeizadeh et. al. (2015) This study aims to examine the exergy efficiency of Al2O3 – water nanofluid as a basic liquid in a flat-platform solar collector by using it as a basic liquid as a basic liquid. Many variables, including mass fluid flow rate, volume of nanoparticles, fluid input collector temperature, sun radiation, and ambient temperatures, are investigated for their effect on the collector's exergy efficiency. Examples include: An interior point method to limit study under the provided conditions was also developed to discover the optimum concentration values for nano-particles, Flow rate for fluid mass and fluid collector for maximal efficiency of exergy delivery under the given circumstances. Each of these variables, depending on the findings, may have a distinct effect on the Exergy of the collector by changing the value of other elements of the equation. According to real-world constraints, the optimum exergy efficiency increases with growing solar radiation value in both pure and nanofluid conditions, according to the results of optimization experiments. The highest collector exergy efficiency is improved by approximately 1% by suspending Al2O3 nanoparticles in the base fluid and the greatest collector exergy effectiveness is increased by approximately 2%. (Water).

Omid Mahian et. al. (2014) The findings are also provided for volume fractions as little as 4% and nanopart sizes as small as 25 nm. Following the first rule of thermodynamics, heat transfer coefficients are greatest in pipes and lowest in nanofluids made of SiO2 and water (see Figure 1). The greatest output temperature is achieved by the nanofluid nonactic Cu/water TiO2, Al2O3, and SiO2/water systems, in that sequence, for the second through fourth highest output temperatures, respectively. Following the results of the second law researching a study of nanofluids, it was discovered that the Cu/water nanofluid was the least entropic of the group. In spite of the fact that TiO2/water nanofluids perform worse in terms of thermal effectiveness when compared to Al2O3/water nanofluids, the entropy generated by TiO2/water nanofluids is lower than that created by Al2O3/water nanofluids. A few recommendations for further study on the use of nanofluids in solar panels are made at the conclusion of the paper.

Rehena Nasrin et. al. (2014) This study investigates the quantitative analysis of Forced heat transfer and convective movement of huge quantities of nanofluids using a solar-powered platform. The solar panel has a flat plate cover and a wavy absorbent sinusoidal absorbent material. As operational fluids in the solar collection, four various nanofluids are used: Ag nanofluid, hydrofluid, Cu nanofluid, water - Al2O3, water -CuO nanofluid, and water -Al2O3. The Galerkin weighted residual method is used in conjunction with For the resolution of partial differential equations with suitable boundaries, use the finite element technique. A systematic investigation of the behavior of various nano-fluids is carried out, which is related to working characteristics such as temperature and speed distribution, radiative and convective transfers, average temperature and speed, and so on. Among the characteristics of this performance is the solid volume fraction phi as compared to the previously mentioned nanofluids. This study demonstrates that the highest possible phi value in a water-based Ag nanofluid may be utilized to improve the functions of heat transfer inside the collector.

Zhong Ge et, al. (2014) The thought of the local coefficient of heat loss is introduced, and the method for calculating the average temperature and the absorber plate temperature of the heat loss coefficient is examined in this study. It also includes the flat plate collector exergy analysis model, which takes into account the fact that the temperature distribution along the absorber plate is not uniformly distributed throughout the plate. The results of the computation are quite close to the results of the tests. Environment temperature, sun irradiation, fluid induction temperature, and fluid mass flow rate are all studied for their effects on usable heat rate, useful exergy rate, and exergy loss rate, respectively. Fluid intake temperature must be at an optimal level in order to get the maximum effective workout rate possible. The predicted optimal temperature for the input fluid is 69 degrees Celsius, and the maximum useable rate of exergy is 101.6 watts. Using the following parameters: ambient temperature, solar irradiation, fluid mass flow rates (20°C, 800W/m2, 0,05kg/s, and 50°C), exergy rate distribution, and fluid mass flow rates (800W/m2, 0,05kg/s, and 50°C). According to the results, the exergy rate is 5.96 percent, with temperature differences between the surface of the plate absorber and solar system radiation accounting for 72.86 percent of the total exergy rate.

Ravikanth S. Vajjha et. al. (2012) This article examines and investigates thermophysical effects, thermal transmission, and temperature and nanofluid concentration pumping capacity. It is shown that the number of Prandtl, Reynolds, and Nusselt functions associated with nanofluid thermophysical properties, as well as these numbers, have a substantial impact on the coefficient of convective heat transfer. The pressure loss and pumping power required for a given amount of heat transfer are dependent on the flow number of Reynolds for a certain amount of thermal transfer. Because of these changes, the temperature and volumetric concentrations of nanofluids vary in their thermophysical properties.

S. Farahat et. al. (2009) The overall aim of this study is to identify the most efficient and optimum design parameters for thermal solar conversion systems that use flat solar collectors as their primary energy source. It is necessary to conduct a comprehensive energy and exercise research in order to assess the thermal and optical performance, exergy flows and losses, and exercise effectiveness of a typical flat panel collector while running under certain operating circumstances. The plate area of the absorber, the size of the solar collector, the diameter of the pipeline, the fluid input, the temperature of the air output, and the overall loss coefficient are all factors that are examined. The development of a simulation software programme for heat calculations and workout computations is underway. The findings of the software are strikingly comparable to the experimental data that has already been published in the academic literature. We were able to establish the exegetically ideal operating circumstances in the end, in addition to the optimal mass-flow rate values, plate area and maximum exergy efficiency. As a consequence, improved results were obtained, and the exergy method was used to its full potential in the construction of solar collectors.

Fabio Struckmann (2008) Because of the large number of factors involved, it is very difficult to conduct an accurate and complete analysis of a solar platform collector. A number of major factors has been integrated into a single equation, and The thermal performance of the heat sink collector was correctly predicted using a mathematical model that was created. In active solar systems, the solar collector is the most essential component to consider. Through the use of an absorbent surface, this device collects solar energy and converts it to heat. Heat is typically transmitted to a fluid that flows past the collector in the majority of instances, which is either air or water. Heating fluid transports heat either directly to the hot water system or indirectly to a storage subsystem, which may be used at night and on cloudy days to provide hot water when needed. It has been shown how to characterize the thermal performance of a flat plat solar collector using one of a number of different methods. The collector efficiency statistic is the most important one to look into. Additionally, there are other factors to consider, such as the overall heat loss coefficient, such as the heat removal factor (FR), do not have constant values, a more precise and complete research should take into consideration this fact.

CHAPTER 3

MATHEMATICAL MODELLING OF FLAT PLATE SOLAR COLLECTOR

3.1. Overview

For a comprehensive study of the flat plate collector's performance in light of the work's goals, a physical model of the compound flat plate collector, as well as a mathematical model of efficiency, is needed. This chapter describes in detail how the physical model for the research was created, as well as all of the formulations that were used to achieve the current work's objective.

When it comes to solar hot water systems, the flat plate solar collector is by far the most essential component. The solar collector thus has to be able to work at its best. As the power equation does not take internal losses into account, Cannot calculate efficiency of a flat plate solar collector. The second law analysis evaluates inefficiencies, relative magneticities and location[1.2] more accurately when it comes to establishing the optimal operating zone. In order to assess the thermal, optical, and exercise performance and to determine optimal mass flux rate, absorber platform area and extreme exercise efficiency under specified operating conditions, the principal aim of this article will be to conduct the analysis of the detailed energy and energy of the flat platform solar collectors. There has been a lot of study in this field. Exergy output, exergy efficiency, and entropy generation are all concepts that are used in the development of thermodynamic models for solar collectors in Refs. [3–8]. However, the total loss coefficient is considered to be constant or computed using an empirical equation with defined restrictions, while the total loss coefficient is not.

3.2. Theoretical analysis

3.2.1. Analysis of the Flat-plate solar collector

Figure 3.1 depicts the flat-plate solar collector that will be investigated in this study, and Figure 3.1 depicts a basic design for the tubed absorber plate that will be investigated in this research . Copper strips are fastened with screws to the top and bottom of the tubes. Copper pipes are the most common kind of pipe because of their superior corrosion resistance.

3.2.2. Dimensions of Flate Plate Collector

Table 3.1 illustrates the Flat-plate solar collector design with fixed parameters. As for the absorber's energy and the energy lost in the absorber the useful heat rate provided by a platform solar collector may be stated below: [19]:

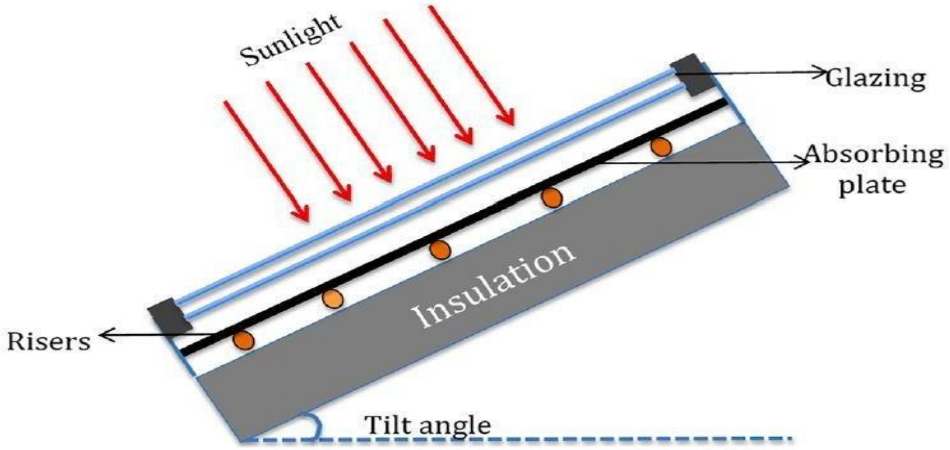
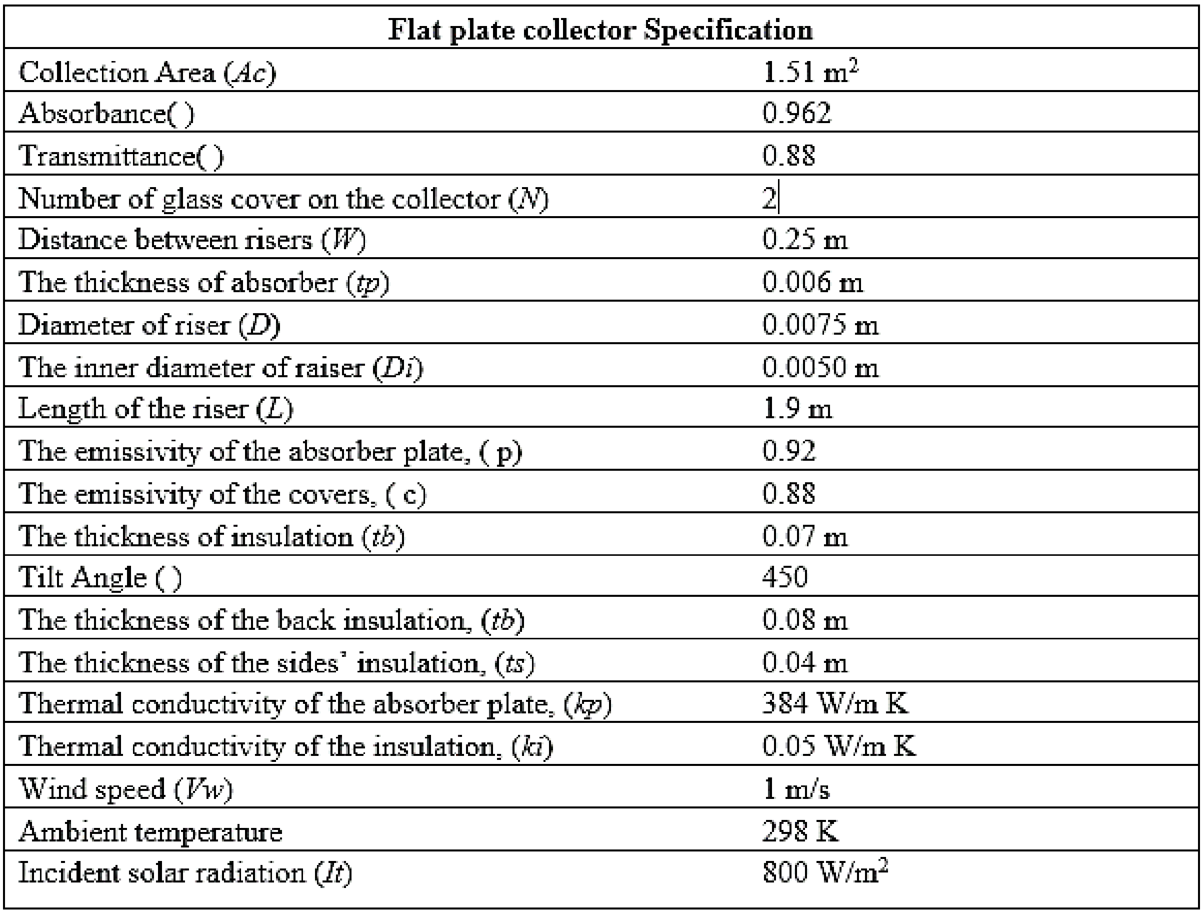


Figure 3.1: Flat plate sola collector

Table 3.1: Specifications for the solar collector under investigation in terms of the environment and design



Flat plate collector Specification	
Collection Area (*Ac*)	1.51 m^2
Absorbance( )	0.962
Transmittance( )	0.88
Number of glass cover on the collector (*N*)	2
Distance between risers (*W*)	0.25 m
The thickness of absorber (*tp*)	0.006 m
Diameter of riser (*D*)	0.0075 m
The inner diameter of raiser (*Di*)	0.0050 m
Length of the riser (*L*)	1.9 m
The emissivity of the absorber plate, (p)	0.92
The emissivity of the covers, (c)	0.88
The thickness of insulation (*tb*)	0.07 m
Tilt Angle ( )	450
The thickness of the back insulation, (*tb*)	0.08 m
The thickness of the sides' insulation, (*ts*)	0.04 m
Thermal conductivity of the absorber plate, (*kp*)	384 W/m K
Thermal conductivity of the insulation, (*ki*)	0.05 W/m K
Wind speed (*Vw*)	1 m/s
Ambient temperature	298 K
Incident solar radiation (*It*)	800 W/m^2

3.2.3. Energy Equation solver Methodology for analysis

The present work uses a thermodynamic model based on the mathematical approach presented in ref [13]. The details of the model and physical interpretation for each term used have been discussed in [14,15]. The properties of all the fluids are temperature-dependent and the temperature changes are accounted for using the EES program. The sources used by the EES program to evaluate the properties of Al_2O_3, Cu, MgO, MWCNT + Fe2O3, nanoparticles can be found in ref. [16–13] respectively. In the

model, The usable temperature absorbed by the PTC work fluid should be determined accordingly:

$$Q_u = \dot{m}_r C_{pr}(T_{ro} - T_{ri})$$

Where $\acute{U}_{rr}$ is a PTC work fluid mass flow rate, C_{pr} is a fluid specific heat, T_{ro} and T_{ri} are the PTC leaving and entering fluid temperatures correspondingly Tri . The usable energy (Qu), produced by the PTC, may be defined in accordance with the total coefficient of heat loss (Ul).:

$$Q_u = A_{ap} F_R \left(S - \frac{A_r}{A_{ap}} U_l (T_{ro} - T_0) \right)$$

A_{ap} denotes the thermal removal factor for aperture area, S denotes the solar radiation absorbed by the recipient, A_r denotes the recipient's aperture area, and Ul denotes the collector coefficient of total thermal loss, which is responsible for the loss of wind convictions, the loss of radiation due to a difference in temperature between the tube and the glass, and the loss of radiation due to a temperature difference.

$$F_R = \frac{m_r c_{pr}}{A_r U_l} \left(1 - \exp\left(\frac{-A_r U_l F_1}{m_r c_{pr}}\right) \right)$$

$$U_l = \left(\frac{A_r}{(h_w + h_{rca}) A_g} \right) + \left(\frac{1}{h_{rrc}} \right)^{-1}$$

where h_w, h_{rca}, h_{rrc} and A_g are the heat convection coefficient of wind, Coefficient radiation heat from deck to environment, coefficient radiation heat from receiver to deck, and the glass cover area, respectively, Using the assumption that the collector's surface is heated to the same local temperature as the working fluid, F1 depicts the relationship between real useful energy and useful energy obtained. It is also possible to address the heat transfer resistance coefficient from the liquid to the surrounding atmosphere. The factor is obtained via the use of an equation. (6):

$$F_1 = \frac{\frac{1}{U_l}}{\frac{1}{U_l}+\frac{D_{ro}}{D_{ri}h_f}+\frac{D_{ro}}{2k_r}\ln\frac{D_{ro}}{D_{ri}}}$$

Depending on the external diameter of the receiver tube (Dro, Dri, hfi, and kr), the internal diameter of the recipient tube, the inner coefficient of heat transfer inside the receptor tube, and the thermally conductive heat transfer of the recipient tube are calculated, as well as their respective values. The convective coefficient of heat transmission (hf) is calculated:

$$Nu = \frac{h_f \cdot D_{ri}}{k}$$

where Nu is the working fluid Nusselt number and is determined by equation:

$$Nu = \frac{(\frac{f}{8})\cdot(R_e - 1000)\cdot P_r}{1+12.7\left(\frac{f}{8}\right)^{0.5}(P_r^{\frac{2}{3}}-1)}$$

The flat plate collector uses the thermal efficiency:

$$\eta_{th} = \frac{Q_u - W_{pump}}{G \times A_{ap}}$$

where G is the solar radiation in W/m^2

The pump work in the PTC could be calculated as follows:

$$W_{pump} = \Delta P \times Vf/\eta_{elect}$$

3.3 Exergy efficiency

The exergy efficiency of the PTC could be calculated as follows:

$$\eta_{ex} = \frac{E_u}{E_s}$$

The useful exergy Eu and solar exergy Es is obtained as follows:

$$E_u = Q_u - \dot{m} \cdot C_p \cdot T_0 \cdot \ln\left(\frac{T_{out}}{T_{in}}\right) - \dot{m} \cdot T_0 \cdot \frac{\Delta P}{\rho_{fm} \cdot T_{fm}}$$

$$E_s = A_c \cdot G \cdot [1 - \frac{4}{3} \cdot \left(\frac{T_0}{T_{sun}}\right) + \frac{1}{3} \cdot \left(\frac{T_0}{T_{sun}}\right)^4]$$

where $T0$, Tfm and $Tsun$ are the ambient temperature, the mean fluid temperature in PTC, and sun temperature, respectively.

The exergy destruction can also be calculated using the following equations:

$$E_{d,\Delta P} = T_0 \cdot \dot{m} \cdot \frac{\Delta P}{\rho} \frac{\ln\left(\frac{T_{out}}{T_{in}}\right)}{T_{out} - T_{in}}$$

$$E_{d,s-r} = \eta_{opt} \cdot E_s - Q_{abs} \cdot \left(1 - \frac{T_{am}}{T_r}\right)$$

$$E_{d,r-f} = Q_u \cdot \left(1 - \frac{T_{am}}{T_r}\right) - E_u$$

Where

$E_{d,\Delta P}$, $E_{d,s-r}$ and $E_{d,r-f}$ are the exergy destruction due to fluid friction, the exergy destruction due to heat transfer from the sun to the receiver, and exergy destruction from the fluid in the receiver. Qabs is the total energy from the sun and ηopt is the reflector efficiency. The total exergy destruction in PTC is the sum of the individual exergy destruction values and is obtained as follows:

$$E_d = E_{d,\Delta P} + E_{d,s-r} + E_{d,r-f}$$

3.4 Thermal properties of the examined nanofluids

Three different nanofluids consisting of copper nanoparticles are compared used in this study. The base fluids used are pressurized water, and used nanoparticles. The nanoparticles volume concentration used in this study ranges between 0 and 6%, and the equations used in this study to ascertain the Nanofluid thermophysical characteristics do not account for the size of the nanoparticles which should range between 10 – 100 nm [26]. The density of the nanofluids (nf) can be calculated from the nanoparticles volume fraction (φ) as follows [27]:

$$\rho \mathrm{nf} = \rho bf.\,(1-\varphi) + \rho np.\,\varphi$$

Nanofluids can determine their specific heat capacity using

$$c_{p,nf} = \frac{\rho_{bf}\cdot(1-\varphi)}{\rho_{nf}}\,.\,c_{p,bf} + \frac{\rho_{np}\cdot\varphi}{\rho_{nf}}\,.\,c_{p,np}$$

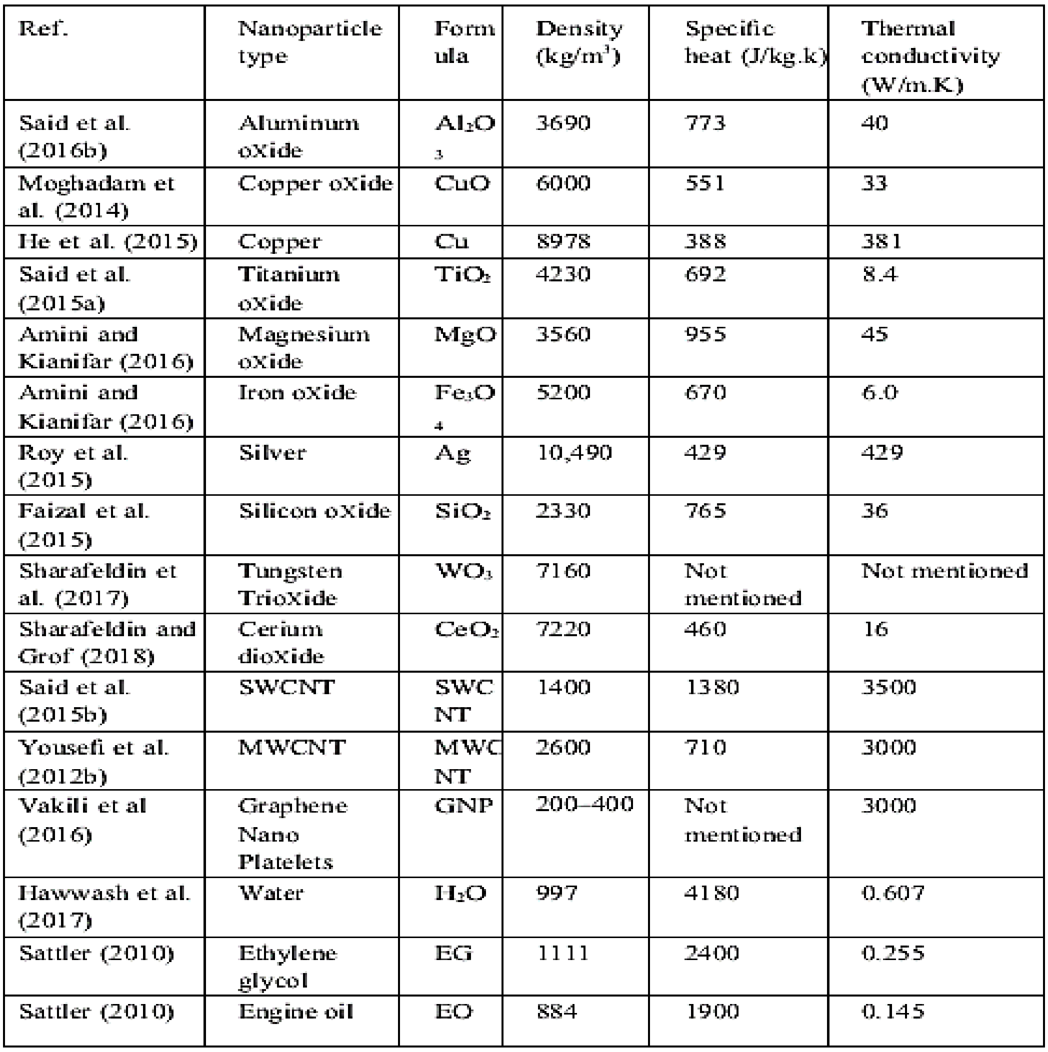
This work presents a comparative and parametric thermal performance investigation of various working fluids operating in the PTC. Furthermore, the effect of adding copper nanoparticles on the thermal performance of water, Therminol VP-1, Syltherm 800 are also investigated, and an optimization is performed to ascertain the optimum condition of nanoparticle concentration, volume flow rate, and input temperature to give the maximum energy efficiency for each working fluid used in the study. The nanofluids used are Cu/water, Cu/Syltherm 800, and Cu/Therminol VP-1, and the results of the study are summarized as follow:

- With increasing flow rates of the working liquid the thermal efficiency of the collector is increased.
- The impact of the input heat is considerably greater than the impact of the flow rate on PTC thermal efficiency.
- The use of nanofluids in the PTC is relevant only in the case of thermal oils while it is not relevant in the case of liquid sodium and pressurized water owing to these fluids' strong thermal characteristics.
- The exergy efficiency for all working fluids evolved with an increment in nanoparticle
- concentration, this is due to the improved convection heat transfer coefficient in the absorber as consequence of nanoparticle loading.

. In an experimental study, Verma et al. (2017) investigated the thermo-physical characteristics of different nanofluid types for particle concentration and temperature, and the findings were published in Nature Communications. In their study, the researchers developed and evaluated a range of nanofluid attentions ranging from 0.25 to 2.0 weight percent of total nanofluids. Their findings revealed that when it comes to improving heat conductivity, the concentration of nanoparticles has a significant effect, as seen in Fig. 1. It is conceivable that this is due to nanoparticles' greater inherent heat conduction capacity as compared to water. Additionally, when the temperature rises, thermal conductivity rises due to the electrified water molecules and nanoparticles in the water. Furthermore, as shown in Fig. 2, the nanofluid viscosity rose according to the increase in nanoparticle weight percentage. The growth of the intermolecular layers leads in increasing frictional resistance between the nanoparticles and neighboring layers of the base liquid. The number of Nusselt and Reynolds depends on the quantity of nanofluids, as well as the pressure loss and friction factor, and this has a major influence on the heat transfer performance of these fluids. Specific heat, on the other hand, is an essential characteristic to consider when characterising nanofluids since it is vital in both the heat transmission and heat storage processes that occur in them. When performing a theoretical study on thermal conductivity, it is essential to incorporate the following parameters: particle size (m), Boltzmann constant (2kg/s2 K), average temperature(K), and dynamic viscosity (Pa s) (Pa s).

Calculating the thermal conductivity of the base fluid (water) was done using the following formula: heat flow studies, energy studies, and exergy studies. According to the findings of Verma et al. (2017), the density of nanoparticles rises, as shown in the picture. In contrast, as the concentration of nanoparticles increases, the specific heat of the nanofluid falls, resulting in an increase in the absorption of nanoparticles and the transmission of heat by the nanofluid. Several distinct nanoparticles and base fluids have varied thermophysical characteristics at varying concentrations, which are summarized in Table 3.1.

Table 3.1: Thermophysical properties of different nanoparticles and base fluids. [Zayed et al. 2019]



Ref.	Nanoparticle type	Formula	Density (kg/m^3)	Specific heat (J/kg.k)	Thermal conductivity (W/m.K)
Said et al. (2016b)	Aluminum oXide	Al_2O_3	3690	773	40
Moghadam et al. (2014)	Copper oXide	CuO	6000	551	33
He et al. (2015)	Copper	Cu	8978	388	381
Said et al. (2015a)	Titanium oXide	TiO_2	4230	692	8.4
Amini and Kianifar (2016)	Magnesium oXide	MgO	3560	955	45
Amini and Kianifar (2016)	Iron oXide	Fe_3O_4	5200	670	6.0
Roy et al. (2015)	Silver	Ag	10,490	429	429
Faizal et al. (2015)	Silicon oXide	SiO_2	2330	765	36
Sharafeldin et al. (2017)	Tungsten TrioXide	WO_3	7160	Not mentioned	Not mentioned
Sharafeldin and Grof (2018)	Cerium dioXide	CeO_2	7220	460	16
Said et al. (2015b)	SWCNT	SWCNT	1400	1380	3500
Yousefi et al. (2012b)	MWCNT	MWCNT	2600	710	3000
Vakili et al (2016)	Graphene Nano Platelets	GNP	200–400	Not mentioned	3000
Hawwash et al. (2017)	Water	H_2O	997	4180	0.607
Sattler (2010)	Ethylene glycol	EG	1111	2400	0.255
Sattler (2010)	Engine oil	EO	884	1900	0.145

3.5. Energy Balance in Flat-Plate Collectors

Energy preservation may be assessed by calculating the energy balance under stable circumstances for thermal analysis of any thermal system, is a fundamental concept that must first be understood. The efficiency of solar collector energy in steady state is different from the total thermal losses produced by the solar radiation that has been collected in the past.

Useful energy = Absorbed solar energy - Thermal losses

The anticipated efficiency of a design produces increment in proportionality with the amount of usable energy produced by the design. Considering the importance of thermal efficiency in this kind of study, it is necessary to evaluate various materials and change collector systems on the basis of this measurement. The goal is to evaluate the efficiency of a range of theoretical calculations that may be found in text books (as well as in this lesson).

Let's start with defining thermal efficiency (), since it will be the chapter's emphasis and ultimate goal.

$$\eta=QuAcGT\eta=QuAcGT$$

where Qu is the collector's usable energy output, GT is the incoming solar radiation flux (irradiance), and Ac is the collector's area. As a result, the denominator equals the collector's total energy input. The GT is the external conditions parameter in this calculation, and It is often generated through real measurements or assumptions of a given location (with a pyranometer). The area of the collector is a technical requirement. So, the major issue here is determining how to calculate the Qu - usable energy.

As previously stated, we must first understand the energy balance inside the collector: absorbed energy minus losses in order to determine how much energy is available for usable thermal work.

The energy balance may alternatively be described using the main equation below:

$$Qu=Ac[S-UL(T_{plate}-T_{ambient})]Qu=Ac[S-UL(T_{plat}e-_{Tambient})]$$

Where S stands for absorbed solar energy, UL for total loss, T plate for absorbing plate temperature, $T_{ambient}$ for air temperature, and A_c for collector area.

On this equation is based the energy balance study in Chapter 6 of Duffie and Beckman's Presentation Book. To answer this issue, we must first understand how to get the numbers S and UL. The following reading provides the most comprehensive explanation. The data on incoming solar radiation provides a fast approximation of absorbed energy (IT):

$$S=(\tau\alpha)avITS=(\tau\alpha)avIT$$

where (α)av is the average transmission and absorption of the plate across different radiation types of collector cover. In reality, based on realistic estimates, $(\tau\alpha)av \approx 0.96(\tau\alpha)beam$. Let us now look at how the radiation losses may be calculated. Please read the following passage. The usable energy gain may now be calculated using the energy balance equation provided above, now that the absorbed radiation and losses have been specified.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Introduction

Flat solar collectors for low temperature heating are utilized in many industrial and domestic applications. Because of their simple design and excellent durability, these collectors are extensively utilized all over the globe. The total impact of a system's components and their interactions is the system's performance. The temperature parameters, environmental conditions, and chemical reactions all need flat plate solar collector schemes to be stable. The combined impact of its components is responsible for these features. A flat plate solar collector's major components are the absorber plate, insulation, clear cover, flow tube, and box. The flow tube and box are two more small mechanisms. Optical characteristics of the absorber effect are utilized to measure the thermal performance of the Flat Plate Solar Collector. The flat plate of a solar collector performance is also used to assess the absorber's design parameters and parameters. The impact of the material's thermal characteristics on the workings of a flat plate solar collector is being investigated. According to the findings, the design flow tube characteristics have an impact on the system's thermal performance. By analyzing the optical and design characteristics of the system, the transparent cover effect is utilized to examine the thermal performance of the system. The thermal performance of the device is influenced by the contact between the plate and the covering of glass. The isolation material employed has an impact on a system's thermal performance.

4.2. Model Validation Analysis

- The findings of the created model are compared to those developed in the literature in this section.
- In terms of thermal efficiency, it is clear that there is very little difference between the data from the model and the literature.
- As a result, this model may be deemed verified.

Solar flat plate collector analysis comprises of two 0,02 and 0,05 kg/s mass flow rate. This study has been based on various outputs parameters energy and exergy analysis of a solar flat plate collector. Four types of nano fluids used in this study i.e., Al2O3, Cu, MgO and one hybrid fluid is MWCNT + Fe2O3.

4.3. Graphical representation of Analysis output parameters for flat plate solar collector at 0.02 mass flow rate.

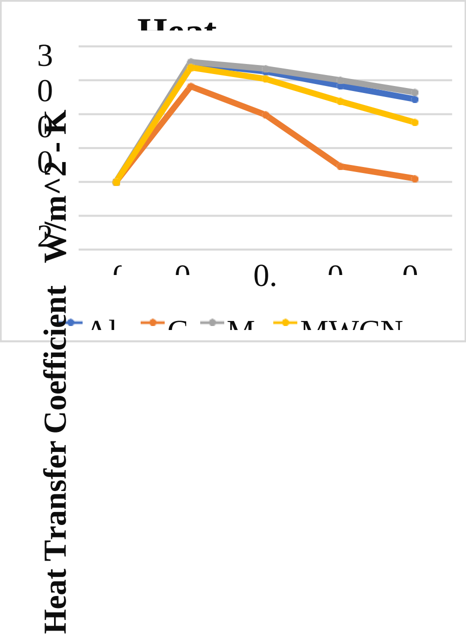


Figure 4.1: Comparison of Heat transfer coefficient and phi values at different nano fluids

As per above graph MgO fluid shows the maximum level of Heat Transfer coefficient and Cu give the minimum heat transfer rate in the flat plate solar collector. Also, we can see from graph that phi values increase but heat transfer decreases from 0.005 value of phi. It gives better results from phi value 0 to 0.005 then heat transfer decreases.it is due to the fact that heat transfer coefficients depends upon Nusselt number , which in turn depends upon the property of the liquid.

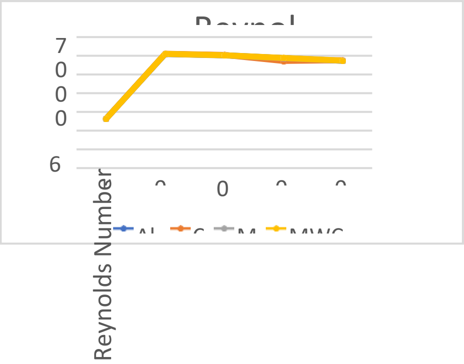


Figure 4.2: Comparison of Reynolds number and phi values at different nano fluids

It can be seen from the graph that the trend of Reynolds number for nanofluids is increasing till the value of phi equal to 0.005 and then it is decreasing but the slope is very less. As Reynolds number depends upon property of the fluid in this case also it is the property of nanofluids that is affecting the value of Reynolds number. Reynolds number is lowest for Cu at a value of phi equal to 0.02. This trend is due to the fact that Reynolds number is directly related to proportionality with density of the fluid and inversely proportional to the viscosity of the fluid.

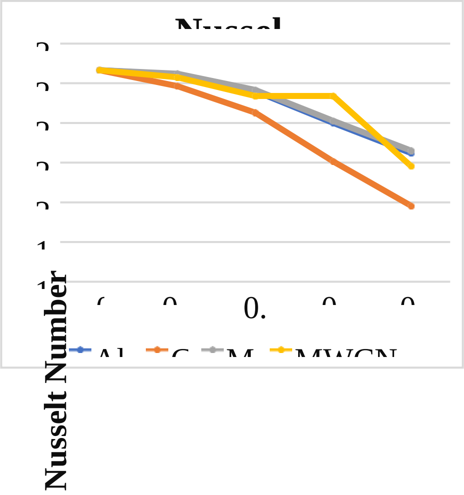


Figure 4.3: Comparison of Nusselt number and phi values at different nano fluids

As per the above graph above graph it is noticeable that Nusselt Number is in the decreasing fashion. It is increasing for MWNCT + Fe2O3 at a phi value of 0.02. the graph also show that Cu has all time low value of Nusselt number and Al2O3 and MgO has comparatively same value of Nusselt number. It can be also seen from the graph that for MWNCT + Fe2O3 starts increasing at value of phi equal to 0.01, increases till 0.02 and then again starts decreasing after that. It is due to the fact that value of Nusselt number depends upon the Reynolds number which in turns depends upon the property of the liquid.

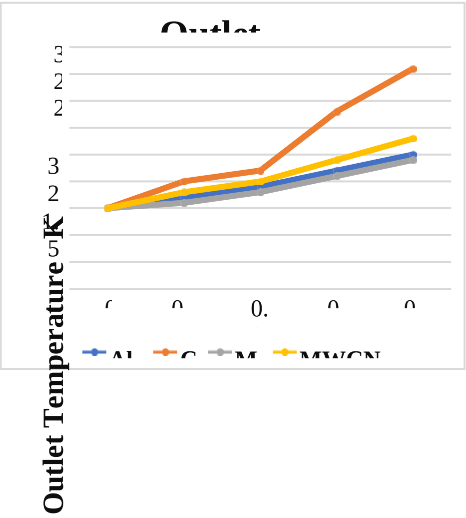


Figure 4.4: Comparison of Outlet temperature and phi values at different nano fluids

The above graph shows us the relation between the value of phi and outlet temperature of working fluid. From the above graph it can be concluded that use of nanoparticle enhances the performance of solar flat plate collector by improving the temperature that can be attained at the outlet. From the above graph it can be seen that Cu provides the highest outlet temperature for any given value of phi and MgO provides the all-time lowest value of outlet temperature. The outlet temperature increases as we increase the value of phi from 0 to 0.03 for all the nanofluids. Cu shows as a drastic change in value of outlet temperature after a phi value of 0.01.

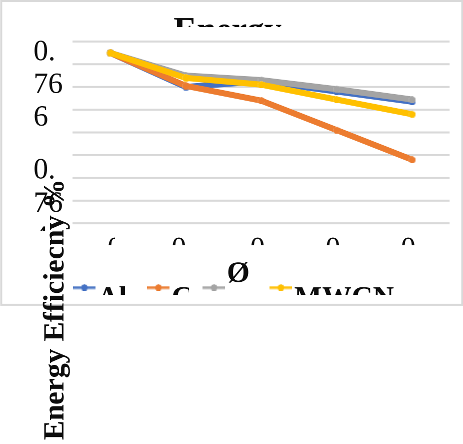


Figure 4.5: Comparison of energy efficiency and phi values at different nano fluids

It is evident from the graph that fashion for first law efficiency is decreasing for all the nanofluid from phi equal to 0 to phi equal to 0.03. Efficiency is Maximum for MgO and minimum for Cu all time. It can be seen from the graph that efficiency of Al2O3 shows different trend, it shows decreasing trend first till the value of phi equal to 0.005 then it starts increasing again till the value of phi equal to 0,01 and then it starts decreasing again till phi equal to 0.03. it can be seen that it is a reverse fashion of outlet temperature obtained by different nanofluids.

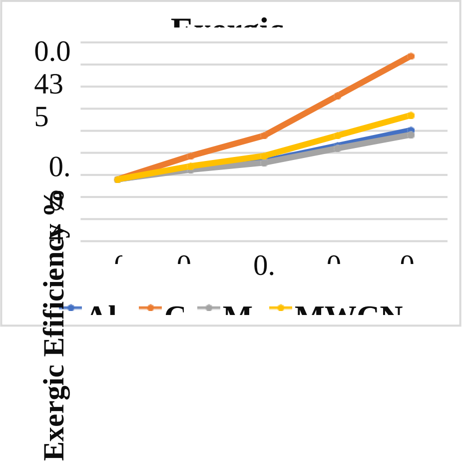


Figure 4.6: Comparison of Exergy efficiency and phi values at different nano fluids

It can be examined and concluded from graph that value of exergic efficiency has a increasing trend for all value of phi for all type of nanofluids. It can be seen that value of exergic efficiency of Cu has all time highest value while, value of exergic efficiency of MgO has all time lower value. It can be also noticed that there is common fashion of drastic increase in value of exergic efficiency after value of phi equal to 0.01 which means after the value of phi equal to 0.01 the increasing slope is highest. The best value of exergic efficiency for all nanofluid is at phi equal to 0.03.

4.4. Graphical representation of Analysis output parameters for flat plate solar collector at 0.05 mass flow rate.

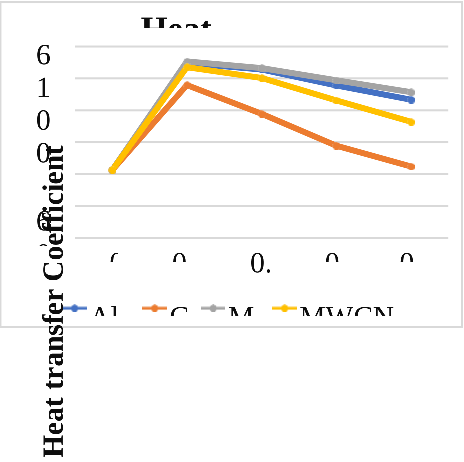


Figure 4.7: Comparison of Heat transfer coefficient and phi values at different nano fluids

As per above graph MgO fluid shows the maximum level of Heat Transfer coefficient and Cu give the minimum heat transfer rate in the flat plate solar collector. Also, we can see from graph that phi values increase but heat transfer decreases from 0.005 value of phi. It gives better results from phi value 0 to 0.005 then heat transfer decreases.it is due to the fact that heat transfer coefficients depend upon Nusselt number, which in turn depends upon the property of the liquid.

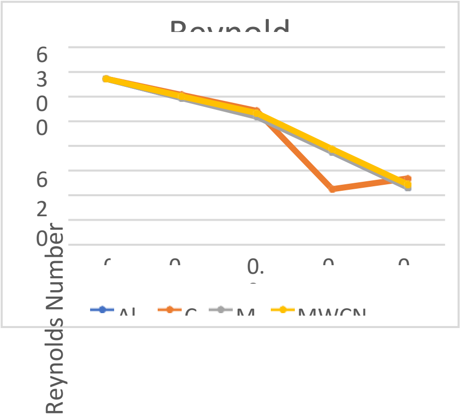


Figure 4.8: Comparison of Reynolds number and phi values at different nano fluids

It can be seen from the graph that the trend of Reynolds number for nanofluids is decreasing. As Reynolds number depends upon property of the fluid in this case also it is the property of nanofluids that is affecting the value of Reynolds number. From the graph it is evident that at the value of phi equal to 0.02 value of Reynolds number of Cu is decreasing drastically then again it starts increasing from there. This trend is due to the fact that Reynolds number is directly proportional to density of the fluid and inversely proportional to the viscosity of the fluid.

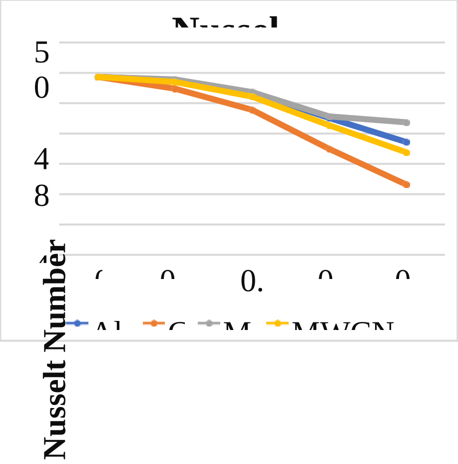


Figure 4.9: Comparison of Nusselt number and phi values at different nano fluids

As per the above graph above graph it is noticeable that Nusselt Number is in the decreasing fashion. the graph also show that Cu has all time low value of Nusselt number and Al2O3 and MgO has comparatively same value of Nusselt number. At the value of phi equal to 0.03 the value of Nusselt number for MgO increases slightly. It is in always decreasing fashion for Al2O3. It is due to the fact that value of Nusselt number depends upon the Reynolds number which in turns depends upon the property of the liquid.

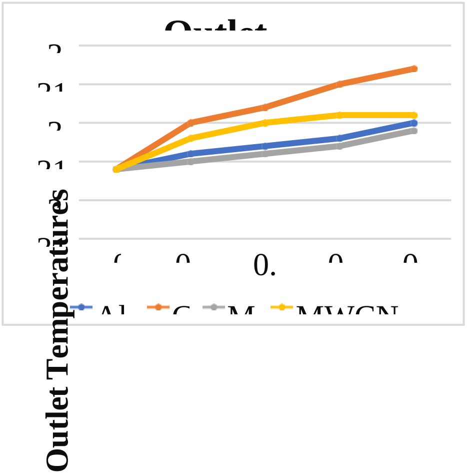


Figure 4.10: Comparison of Outlet temperature and phi values at different nano fluids

The above graph shows us the relation between the value of phi and outlet temperature of working fluid. From the above graph it can be seen that use of nanoparticle enhances the performance of solar flat plate collector by improving the temperature that can be attained at the outlet. From the above graph it can be seen that Cu provides the highest outlet temperature for any given value of phi and MgO provides the all-time lowest value of outlet temperature. The outlet temperature increases as we increase the value of phi from 0 to 0.03 for all the nanofluids. It starts decreasing for MWCNT + Fe2O3 as we increase the value of phi from 0.02 to 0.03.

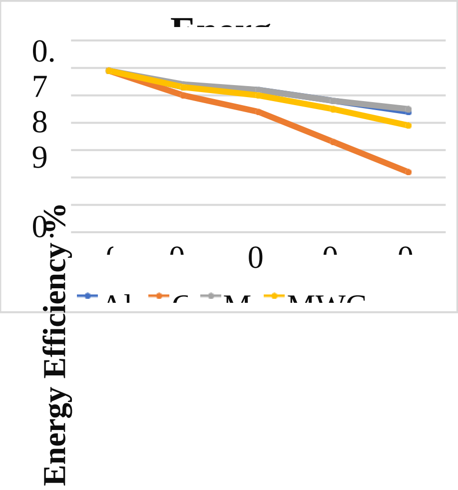


Figure 4.11: Comparison of energy efficiency and phi values at different nano fluids

It is evident from the graph that fashion for first law efficiency is decreasing for all the nanofluid from phi equal to 0 to phi equal to 0.03. Efficiency is Maximum for MgO and minimum for Cu all time. It can be seen from the graph that efficiency of Cu shows different trend, it shows decreasing trend first till the value of phi equal to 0.005 with a higher slope then it starts decreasing again till the value of phi equal to 0,01 with a little flat slope and then it starts decreasing again till phi equal to 0.03 with the higher slope. it can be seen that it is a reverse fashion of outlet temperature obtained by different nanofluids.

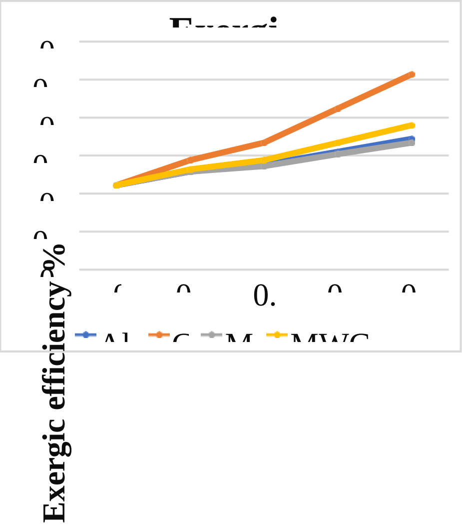


Figure 4.12: Comparison of Exergy efficiency and phi values at different nano fluids

It can be seen from graph that value of exergic efficiency has a increasing trend for all value of phi for all type of nanofluids. It can be seen that value of exergic efficiency of Cu has all time highest value while, value of exergic efficiency of MgO has all time lower value. It can be also noticed that there is common fashion of drastic increase in value of exergic efficiency after value of phi equal to 0.01 which means after the value of phi equal to 0.01 the increasing slope is highest. The best value of exergic efficiency for all nanofluid is at phi equal to 0.03.

CHAPTER 5

CONCLUSION

5.1. Conclusion

This work presents a comparative and parametric thermal performance investigation of various working fluids (pressurized water, Al_2O_3, Cu, and MgO) operating in the PTC. Furthermore, the effect of adding copper nanoparticles on the thermal performance of water, hybrid fluid MWCNT + Fe_2O_3 are also investigated, and an optimization is performed to ascertain the optimum condition of nanoparticle concentration, volume flow rate, and input temperature to give the maximum energy efficiency for each working fluid used in the study. The results of the study are summarized as follow:

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