PROJECT REPORT

"DESIGN AND ANALYSIS OF MODIFIED TUBE RECIEVER FOR PARABOLIC TROUGH COLLECTOR"

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ABSTRACT

In this project, thermal energy storage (TES) tank is introduce along with parabolic trough collector. The purpose of the TES tank is to minimize the fluctuation of thermal flux to get stable temperature at the outlet of the system. The main purpose of this project is to enhance the thermal efficiency of parabolic trough solar collector using modified tube receiver. First experiment is done on the traditional or conventional tube receiver using water as heat transfer tube. Then experiment is done by designing the modified receiver tube with different phase change material. By comparing the thermal behavior of two tubes this research aims to identify the optimal configuration for maximizing the PTC's efficiency and achieving consistent outlet temperature, ultimately enhancing the system reliability and potential applications.

Chapter 01

ELEMENTARY CONCEPTS

1.1 INTRODUCTION

A parabolic trough is a kind of solar thermal collector that has a polished metal mirror along it. It is straight in one dimension and curves like a parabola in the other two. The focal line, where objects meant to be heated are positioned, is the path along which the sunlight that enters the mirror parallel to its plane of symmetry is focused. Concentrating solar collectors require a precise shape in order for all incoming sunlight to reflect off the surface and arrive at the same focal point, regardless of which area of the collector receives the sunshine first.

For residential use, concentrating solar collectors often take the form of a "U-shaped" parabolic trough that directs solar radiation onto an absorber heat tube known as a receiver.

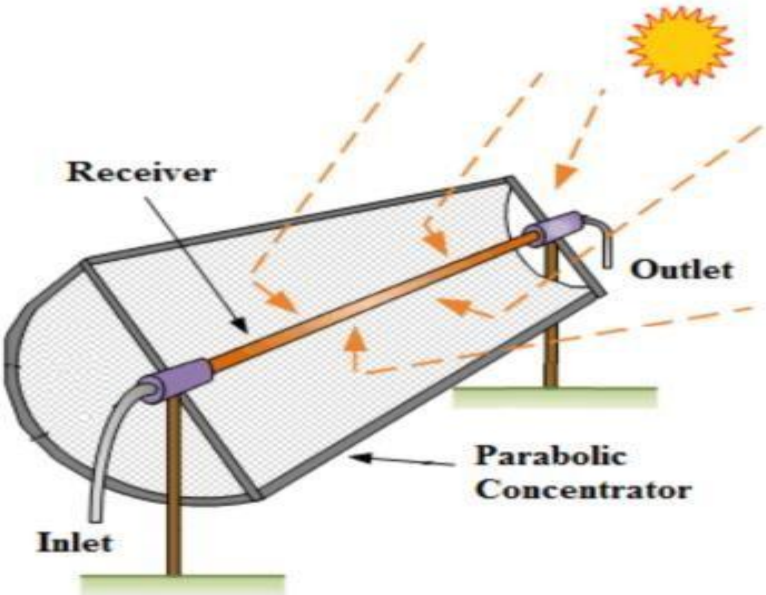


Figure 1.1: Experimental Platform of Parabolic Trough Collector

Typically oriented along a north-south axis, parabolic troughs are rotated to follow the sun's path across the sky from dawn to dusk. Compared to conventional flat panel collectors, solar concentrators with parabolic troughs offer a much higher working temperature range and a high efficiency of about 12% due to their tiny absorber area, which results in reduced heat losses

1.2 PARABOLIC TROUGH TECHNOLOGY

The components of the parabolic trough concentrator (PTC) include a circular cylindrical receiver that is positioned along the parabola's focus line and a cylindrical concentrator with a parabolic cross-sectional form. Direct sun radiation is reflected onto a receiver tube situated in the parabola's focal line. Direct solar radiation is therefore concentrated since the collection aperture area is larger than the receiver tube's outside.

1.3 UNDERLYING PRINCIPLE

In its linear focus receiver, the parabolic trough concentrator (PTC) transforms sun beam radiation into thermal energy. All of the focal points at each concentrator cross-sectional position make up the focal line, which is the surface onto which the beam radiation is reflected. To improve the absorptivity of the receiving tube, selective coating is applied. To prevent any convective heat losses, it is often enclosed in a glass tube. In order to maintain the trough aperture facing the sun at all times, the trough assembly monitors the sun along a single axis. Typically, the trough is positioned with its focal axis parallel to the east-west or north-south directions.

1.4 END-USE APPLICATIONS

Any low to medium process heat application uses a parametric trough. It can reach a maximum temperature of 250°C, depending on the needs of businesses, residences, and religious buildings, among other places. On a clear, sunny day, a conventional parabolic trough with a 6 m2 aperture area may provide 2 kW of heat.

1.5 METHODOLOGY

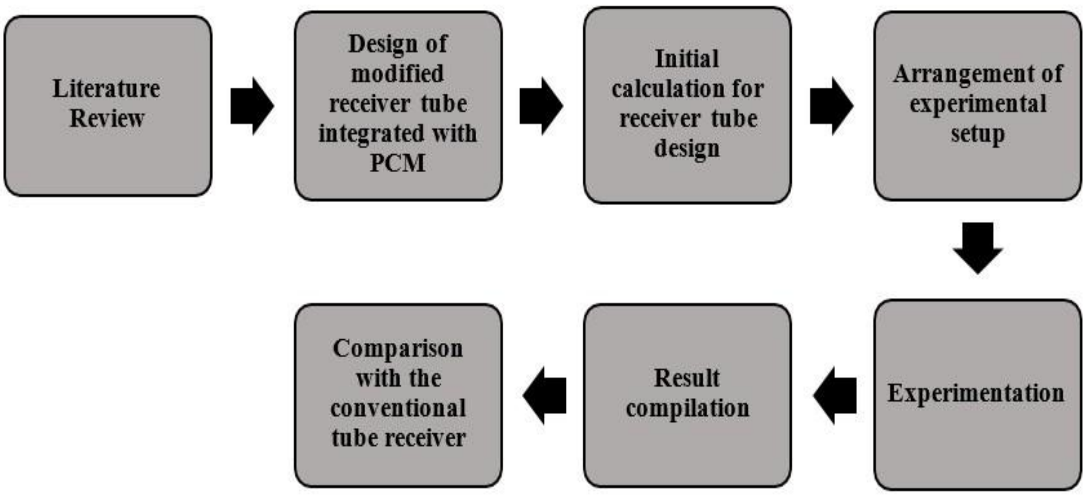


Figure 1.2: Flow chart of project methodology

1.6 AIMS AND OBJECTIVES OF WORK

- The main objective of this work is the thermal performance enhancement of parabolic trough solar collector using modified tube receiver.
- Introduce a short-term thermal energy storage system with collector tube to have stable temperature at the outlet of the trough collector.
- Implementation of phase change material (PCMs) based thermal energy storage system with tube for system working in short off sun duration.
- Detailed analysis of the thermal storage capacity of the storage system and it melting/solidification behavior of the PCM. Comparison of results with the conventional tube receiver.
- The primary goal of this endeavor is to optimize the collection and utilization of solar energy through innovative thermal energy storage solutions.

Chapter 02

LITERATURE REVIEW

2.1 USAGE OF NANOFLUID IN SOLAR ENERGY

Engineered suspensions of solid particles smaller than a nanometer in a base fluid are known as nano fluids. The thermal conductivity of energy transmission fluids can be greatly increased by suspending tiny solid particles in them. This is a creative and efficient method of improving the fluids' heat transfer properties.

2.2 APPLICATION OF NANOFLUID IN PTC

For process heat applications, solar collectors utilized, the liquid such as water or oil serving as the base fluid. A liquid with high thermal conductivity, high heat transfer coefficient, high critical heat flux (CHF), and high specific heat capacity will be able to transfer the most heat from the collector. All of the aforementioned qualities are not achievable for commonly used fluids; however, this can be accomplished by incorporating a small number of nanoparticles into the base fluid, which can then be utilized as a new type of enhanced heat transfer fluid (HTF).

First, the efficiency, financial, and environmental aspects of nanofluid applications in solar collectors and water heaters are examined. The optical characteristics of nanofluids and the experimental investigation of thermal conductivity conducted by some authors are also reviewed.

2.3 EXPERIMENTAL STUDIES

Thirty percent of research investigations concerning the use of nanofluids to increase PTC efficiency have been conducted experimentally. The most effective nanofluid has been determined by examining the effects of various nanofluids with varying percentages of nanomaterials. The majority of them observed that using nanofluid in PTC results in increased thermal efficiency as compared to using base fluid. In this regard, Potenza et al. [1] examined a novel method for analyzing gas-phase nanofluid in PTC using CuO Nano powder. The study finds no appreciable increase in thermal efficiency. The next year, Kasaiean [2] assessed the efficacy of MWCNT/water nanofluid in PTC using MATLAB code and saw a 15% increase in the convective heat transfer coefficient. In early 2011, Taylor et al. [3] examined graphite nanoparticles using thermominol VP-1 as a base fluid in a dish collector, demonstrating an 11% increase in efficiency. After conducting experiments with ZnO, MgO, and Al2O3, Li et al. [4] concluded that ZnO is most suited for nanofluid applications in solar collectors. Al2O3, CuO, and SiO2 nanoparticles were disseminated in a base fluid combination of water and ethylene glycol, as examined by Vajjha and Das (2012). The heat transfer coefficient increased by 31.9% when Al2O3 nanofluid was added at a 1% concentration. The study is only relevant in colder climates, though.

Many researchers have conducted experimental and numerical studies to investigate the thermal performance of an ETC integrated with PCM. Heyhat et al. [5] combined PCM with porous metal foam that is highly thermally conductive in order to enhance lithium-ion battery thermal management. Comparing a lithium-ion battery with pure PCM to one with PCM and porous metal foam integrated, they found a temperature drop of 4-6 K. Furthermore, they asserted that, in comparison to lithium-ion batteries with nano-PCM, those integrated with PCM and metal foam showed more effective temperature management. A detailed review of the impact of adding nanoparticles to PCM was conducted by Nawsud et al [6]. Additionally, they investigated the HPETC's thermal response when a nanofluid was employed as the heat transfer fluid (in the manifold). They asserted that the energy and exergetic efficiency of parabolic trough collectors (PTC) may be increased by using NEPCM and nanofluid. Pawar, V, R; and Sobhansarbandi, S; [7] In this study, the integration of high thermal conductivity porous metal with PCM improves the thermal performance of the HPETC system. Three days in a row are dedicated to the experimental analysis (April 9–11, 2022). The proposed approach is shown to be viable in commercially available systems using two large-scale HPETC systems. To maintain the same absorber area, both methods use the same number of evacuated tubes. Two evacuated glass tubes that are empty are fitted in one system.

This paper investigates the thermal performance of a parabolic trough solar thermal power (PTC) system, which is crucial for solar energy utilization. The FEM method and ray-tracing method were used to compute the solar energy flux profile. The heat transfer process and the impact of operation parameters on HCEs were also numerically investigated. The main findings reveal that the solar energy flux distribution in the circumferential direction is non-uniform, and the CTD of the absorber increases with the increment of the DNI and decreases with the increase of the temperature and velocity of the HTF inlet. The HTF temperature difference decreases with the increase of the inlet velocity, increases with the rising DNI, and almost remains the same with the increase of the inlet temperature. The results provide a fundamental reference for the development of parabolic trough solar thermal power plants in China. Wang, Y., Liu, Q., Lei, J. and Jin, H., [8]

This paper uses computational fluid dynamics (CFD) to analyze the shortcomings of existing air-filled annulus receivers, focusing on convection losses. The study simulated heat transfer mechanisms for conventional receivers, considering thermo- physical parameters like wind velocity and mass flow rate. A one-side insulated receiver was simulated and compared to the conventional receiver, resulting in a more uniform and homogeneous angular temperature distribution in the absorber tube. The reformed receiver outperformed the conventional one by a maximum of a 20% reduction in overall heat transfer. Comparative figures of convective heat loss were estimated for both receivers at different mass flow rates of HTF, with a lower percentage of conventional loss increase observed with an increase in wind speed. The study aims to provide a fundamental point of reference for improving low- temperature application PTC plants in India by redesigning the insulated, reformed receiver system for low-temperature parabolic trough applications. This approach aims to improve the performance of PTC plants in low-temperature applications. Chandra, Y, P., et al [9]

This review paper explores the use of parabolic trough concentration (PTC) in solar focusing processes, focusing on various parameters and improvements to enhance its efficiency. Key findings include the importance of Nusselt and Reynolds numbers for PTC efficiency, the high heat output of PTC, and the use of porous materials and techniques. The study also highlights the benefits of using HTF-melted salt for PTC, with NDAPTC collector performance being 10.3% higher than CIAPTC collector efficiency. The use of Cu nanofluid increases receiver efficiency, evacuated receiver, and bare tube performance. The aluminum tube's performance is 25% higher than that of a that of a steel tube with Al2O3 nanofluid as HTF. The study also discusses desalination in hybrid one-axis solar systems, comparing parabolic troughs and direct steam generation systems. The findings can guide future research and experimental work on modified parabolic trough collector designs. Naveenkumar, at, al [10]

The paper concludes the performance of existing parabolic trough power plants has shown their robustness and excellent performance in the commercial power industry. Technological progress has been made since the last plant was built, making the next generation more competitive with enhanced features like economical thermal storage. Worldwide R&D efforts are expected to drive costs down and improve the performance of this renewable energy option, potentially competing directly with conventional fossil-fuel power plants in mainstream markets. Price, at, al [11]

This study provides an understanding of design parameters and state-of-the-art in CSP technology. The eight-step procedure is simplified but offers a practical tool for initial research, especially in universities with limited CSP studies. A 1.2 kW prototype costing less than 130 dollars is an affordable option. Analyzing alternative materials, such as plywood, galvanized steel with aluminum foil, and aluminum foil, can help researchers develop practical studies with limited budgets. However, plywood is not recommended due to its poor performance and requires more repair. The modular system allows for prototype improvements without rebuilding the equipment, and its ease of assembly and disassembly makes it a valuable tool for initial research. Torres, at, al [12]

Algeria is exploring the use of parabolic trough solar thermal power plants to address increasing energy demand and environmental issues caused by fossil fuel use. The country's favorable climatic conditions make it an attractive location for such plants. The study predicts monthly mean daily direct solar radiation potential, with the Sahara for Ghardaia having the most significant potential at 20 MJ/m2. The results show that increasing HTF and absorber temperature leads to increased heat loss and decreased heat gain. The study also evaluates the performance of various heat transfer fluids in Algerian climatic conditions. The Syltherm 800 is the most recommended fluid, with temperatures between 700 K and 800 K. The study also compares the influence of HTF price on thermal energy cost, finding that the Santotherm LT has the highest thermal energy cost at 129 US $/kW h/day. The study also shows that the best monthly heat gain is observed in increasing direct solar radiation locations, particularly in the south of Algeria. The choice of HTF depends on factors such as temperature range, cost, and availability. Ouagued, at, al [13]

EXPERIMENTAL SETUP

The basic experimental setup has been prepared including the parabolic reflector and receiver tube. The structure material is stainless steel. Fig, shows the experimental setup for this experimental analysis.

Figure 3.1: Parabolic Trough Collector

3.1 COMPONENTS OF PROJECT

1) Parabolic reflector
2) Receiver tube
3) Phase change material (PCM)
4) Multimeter
5) K-type thermocouples
6) Heat transfer fluid
7) Control valve

3.1.1 Parabolic Reflector

This is the main component of the PTC system, which is usually a long, parabolic-cross-sectioned, curved mirror. The focal line, which is a straight line at the bottom of the trough, is where incoming sunlight is focused by the reflecting surface. For parabolic trough reflector we use reflected film of steel having length of 6.9ft and having width of 5.5ft.

Figure 3.2: Parabolic reflector

3.1.2 Receiver Tube

This is a long, cylindrical tube that is placed parallel to the parabolic reflector's focal line. An essential part of a Parabolic Trough Collector (PTC) system is a receiver tube. This is the region where solar radiation is taken in and transformed into heat. For this experimental setup two types of tubes are used:

- Reference tube
- Modified receiver tube

Reference tube: A receiver tube is a hollow tube of steal with dimensions of 28mm diameter and 2.1m length. Heat transfer fluid is flowing through this tube. No phase change material is integrated in this tube and this tube is used as reference tube.

Modified receiver tube: Modified receiver tube is basically consisting of inner tube and outer tube. Inner tube is hollow having diameter of 28mm and length 2.1m. The heat transfer fluid flow through this tube. Outer tube having diameter 50mm and length 2m. The mixture of phase change materials (KNO_3 & $NaNO_3$) are integrated in this tube. Outer tube having large diameter to absorbed more solar radiations to give high output.

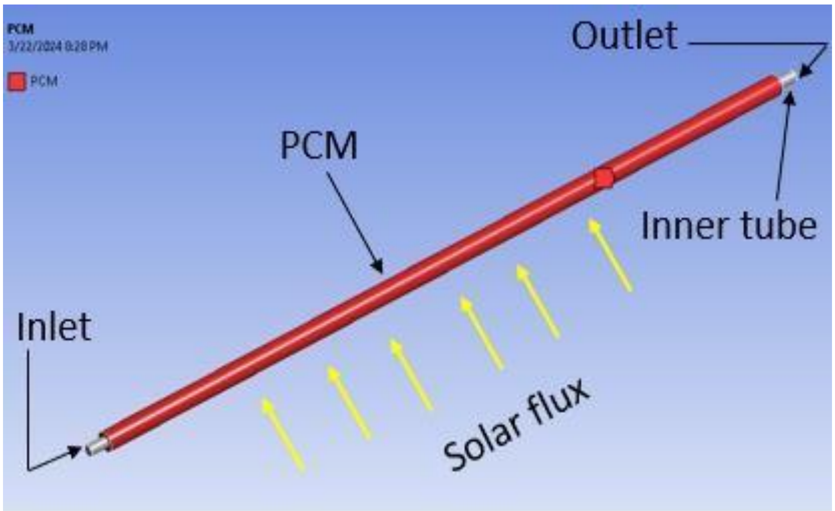
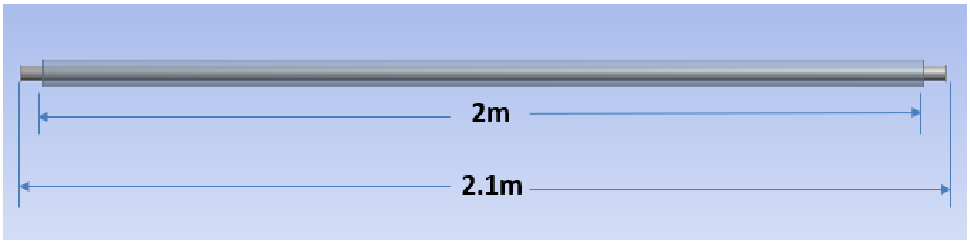
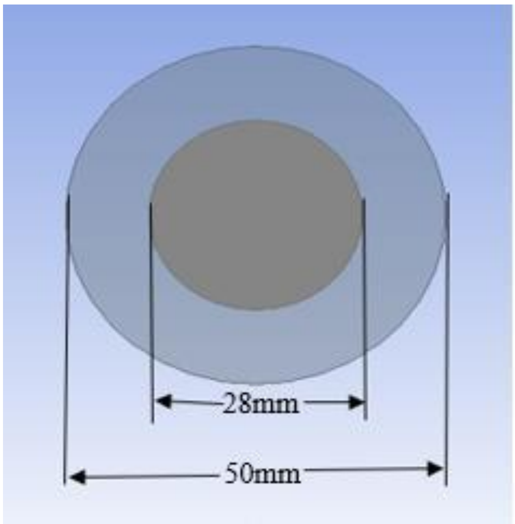


Figure 3.3: Design of modified receiver tube



(a) Front view of modified tube



(b) Side view of modified tube

Figure 3.4: (a) Front view of modified tube (b) Side view of modified tube

3.1.3 Phase Change Material (PCM)

A substance that physically changes at a particular temperature, usually from a solid to a liquid or vice versa, is known as a phase change material (PCM). Because a large amount of heat is absorbed or released during this phase change, PCMs are perfect for thermal energy storage. In parabolic trough collectors, PCMs are indicated to enhance the system's efficiency and thermal performance. The PCMs select for the experimental setup are potassium nitrate (KNO3) and Sodium Nitrate (NaNO3).

In Parabolic Trough Collectors (PTC), two interesting Phase Change Materials (PCMs) are potassium nitrate (KNO3) and sodium nitrate (NaNO3). In solar thermal systems, both salts have advantageous qualities for temperature stabilization and thermal energy storage. Similar benefits are shared by KNO3 and NaNO3, including chemical stability, a high latent heat capacity, appropriate phase change temperatures, and comparatively inexpensive costs.

(a)

(b)

Figure 3.5: (a) Potassium Nitrate (b) Sodium Nitrate

3.1.4 Multimeters

Multimeters are a type of measurement tool that are capable of measuring many electrical properties. In our experimental setup, we used multimeters to monitor the temperature of the solar receiver at several locations, including the base, lower side of the base, center aperture, outside the receiver, and cavity center.

The multimeter we employed in our experimental configuration is important for precisely detecting the temperature up to 2000 Kelvin.

Figure 3.6: Multimeter

3.1.5 K-type Thermocouples

An electrical tool for measuring temperature is a thermocouple. To measure the temperature of the solar receiver, we employed K-type thermocouple wires.

Characteristics:

- K-type thermocouple cables are frequently used to gauge high temperatures.
- The temperature range that K-type thermocouple wires can measure is -200 to 1600 degrees Celsius.
- Thermocouple wires of the K type work better and are more efficient.

Figure 3.7: K-type thermocouple

3.1.6 Heat Transfer Fluid

As concentrated solar energy passes through the receiving tube, a fluid absorbs it. Melted salts and synthetic thermal oils are examples of common HTFs. The decision is based on the system's intended operating temperature range. The HTF's temperature increases as it absorbs heat. In this experimental setup, initially we used the water as a heat transfer fluid. The specific heat capacity of water is 4.184 J/g. K and having density 998.2 Kg/m^3.

3.1.7 Control Valve

A control valve is a tool used to manage a system's fluid flow rate, whether it steam, gas, or liquid. As the last control element, it modifies the flow passage size in response to a signal from a controller. By adjusting the fluid flow, this makes it possible to precisely manage a number of process parameters, including pressure, temperature, and liquid level. As per requirement, the range of the control valve is from 0.1 L/min to 1 L/min.

Figure 3.8: Flow control valve

METHODOLOGY

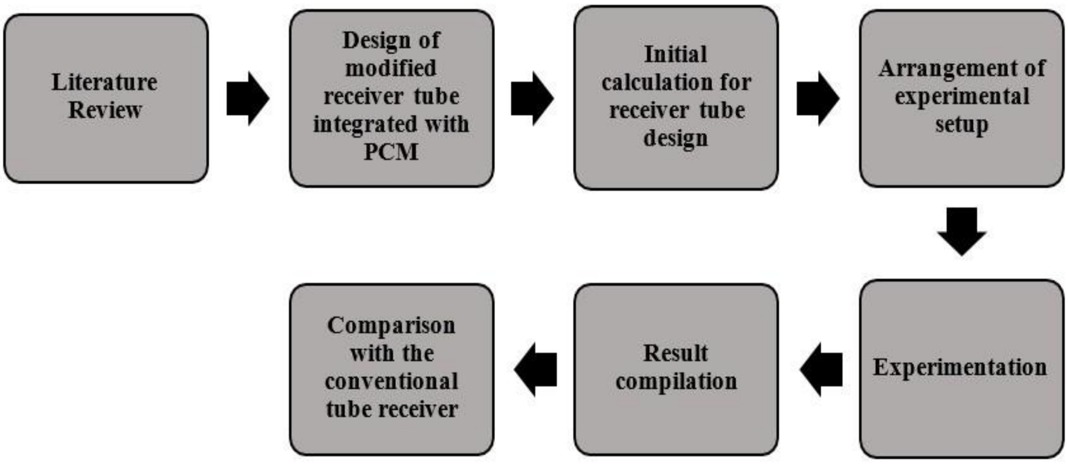


Figure 4.1: Flow chart of project methodology

4.1 LITERATURE VIEW

PCM Types: Examine various PCMs that are frequently utilized in PTC systems, including salts (such KNO3, NaNO3, and paraffin waxes), organic compounds, and salts. PCM Integration Methods: Investigate many ways to integrate PCMs into PTCs, such as inserting them into the receiver tube, utilizing independent storage tanks, or adding heat exchangers powered by PCMs.

PTC Design Specifications: Consider the PTC design specifications, including the tracking system, receiver tube material, focal length, and collector area.

Sun Irradiance and Ambient Conditions: To determine whether PCMs are suitable for thermal energy storage, analyze the data on sun irradiance and ambient temperature for your particular region.

Data Collection and Analysis: Describe the steps involved in gathering data, including measuring the system output, collector temperature, PCM temperature, and solar irradiation. Statistical analysis is one of the data analysis methods.

Assessment of Performance Measures: Determine the essential performance indicators for the PTC-PCM system, including temperature stability, energy storage capacity, and thermal efficiency.

4.2 DESIGN OF MODIFIED RECEIVER TUBE INTEGRATED WITH PCM

The following procedures make up the methodology for creating a modified receiver tube integrated with phase change material (PCM) in a parabolic trough concentrator (PTC). Modified receiver tube consists of inner and outer tube. Inner tube is open at both ends having length 2.1m and diameter of 28mm while outer tube is closed at both ends in which PCM is indicated having length 2m and diameter of 50mm. It optimizes the thermal performance and reduce thermal losses by adjusting the tube geometry, PCM location, and flow channel setup.

4.3 INITIAL CALCULATION FOR RECEIVER TUBE DESIGN

In this section initial calculation was made by using information on solar irradiance and the optical efficiency of the concentrator, calculate the expected solar flux at the receiver tube. This computation considers the tracking precision, focal length, and aperture area of the concentrator. Then using the surface area of the tube and the expected solar flux, determine the heat transfer rate to the receiving tube. This entails using the necessary heat transfer correlations while taking the working fluid's properties, surface characteristics, and tube material into account. Finally, calculate the receiver tube's temperature distribution. In order to do this, the energy balance equation must be solved, considering elements like radiation losses to the environment, convection to the working fluid, and heat conduction inside the tube.

4.4 ARRANGEMENT OF EXPERIMENTAL SETUP

A crucial step in guaranteeing precise and trustworthy data collection is setting up the experimental equipment in a parabolic trough collector. This calls for the tracking mechanism, receiver tube, and collector to all be positioned precisely. Using the subsequent methodical approach, the ideal configuration can be attained.

4.4.1 Positioning the Collector:

The best place for the parabolic trough collector to receive the most direct sunlight of the day is where it should be placed. To optimize solar exposure, this often entails pointing the collector north in the southern hemisphere and south in the northern hemisphere.

4.4.2 Aligning the Receiver Tube:

The parabolic reflector's focus point and the receiver tube, which takes in solar radiation and transforms it into heat, need to be precisely lined up. By doing this, the tube is guaranteed to get the most sunlight possible, which maximizes energy absorption.

4.4.3 Tracking Mechanism Calibration:

A straightforward yet efficient way to guarantee that a parabolic trough collector stays in line with the sun's path during the day is to use a human tracking device. The collector rotates by around 1 degree every 15 minutes. By adjusting for Earth's rotation, this system makes sure that the collector's focal point is still illuminated by the sun's rays.

4.5 EXPERIMENTATION

The experiment's methodology entails methodically evaluating the modified receiver tube's and the basic steel tube's performance in various scenarios. This involves modifying flow rates, solar radiation levels, and other pertinent variables to evaluate the effect on the efficiency of energy absorption and conversion.

Each tube has temperature sensors placed at its input and outflow to monitor the temperature differential, which is then utilized to determine the amount of energy absorbed. The incident sun energy is also recorded by solar radiation sensors. To ensure accurate measurements and remove transitory effects, data collection is delayed until the system reaches steady-state conditions. For analysis, the gathered data—which includes flow rate, temperature readings, and sun radiation data—is recorded on a regular basis.

4.6 RESULT COMPILATION

Analysis and summarization of the data gathered from the experiments with the modified receiver tube and simple steel tube are necessary in the compilation and result stage of the parabolic trough collector comparison. This entails figuring out essential variables under various flow rates and solar radiation situations, such as energy absorption, conversion efficiency, and performance ratios. It is possible to display the data in tabular or graphical representations, making comparison and visualization simple. Based on the investigation, important conclusions and findings that emphasize the benefits and drawbacks of each type of tube should be made. It is also important to talk about any notable variations in performance between the modified receiver tube and the basic steel tube, as well as possible reasons for these variations. In the end, the process of compiling and presenting the results ought to yield a succinct and lucid synopsis of the experimental discoveries, thereby augmenting a thorough comprehension of the operational attributes and possible uses of parabolic trough collectors including disparate receiver tube configurations.

4.7 COMPARISON WITH THE CONVENTIONAL TUBE RECEIVER

A thorough experimental methodology is required to compare the performance of a modified receiver tube with a basic steel tube in a parabolic trough collector. In order to evaluate the effect on energy absorption and conversion efficiency, this entails adjusting flow rates and solar radiation conditions. By comparison, it is feasible to evaluate the success of the receiver tube changes and gain important insights into the performance characteristics of the two tubes.

RESULTS AND DISCUSSION

The results of the experimental examination of the parabolic trough collector will be discussed in this section. To assess the collector's performance, the outcomes will be contrasted with modified receiver tube and reference receiver tube. We'll go into great detail about important variables including temperature distribution, heat absorbed, flow rate and thermal efficiency. The main topics of discussion will be how to evaluate the data and make inferences about the parabolic trough collector's usefulness and future uses. The experimental results of reference receiver tube that were achieved by adjusting the working fluid (water) flow rates via the parabolic trough collector at various time intervals are shown in this section. The reference receiver tube's heat absorption a key indicator of the collector's thermal performance will be the main focus of attention. The relationship between flow rate and heat absorption will be ascertained by analyzing the data.

Figure 5.1 shows the effect of flow rate on the performance of the parabolic trough collector, experiment was carried out with a reference receiver tube at different times of the day and under different flow rate conditions. The findings showed a clear relationship between heat absorption and flow rate. Greater flow rates led to greater outlet fluid temperatures because the collector's capacity to absorb and transfer solar energy.

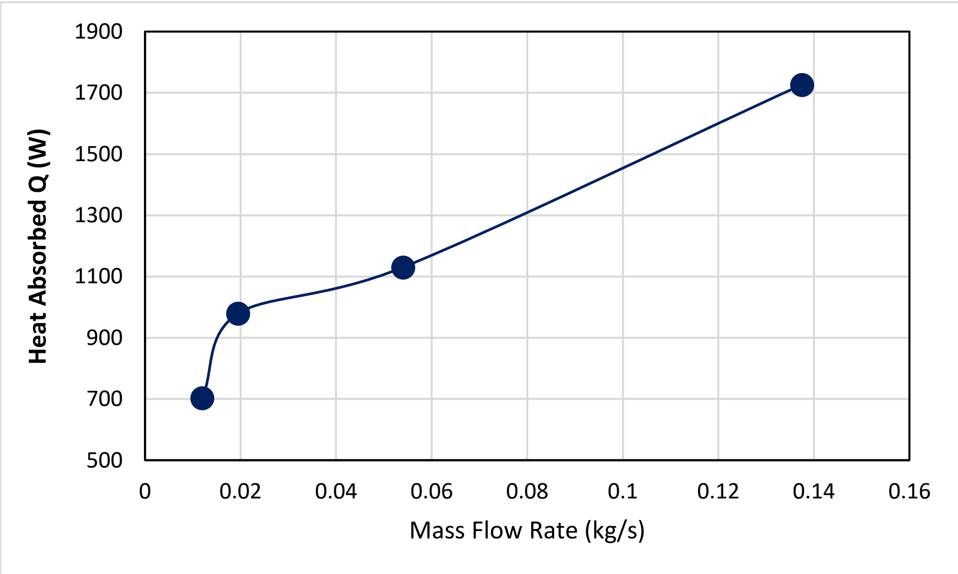


Figure 5.1: Variation of Q with the change of mass flow rate of reference receiver tube

The working fluid (water) flow rate was kept constant at different interval of time in evening to see how the decrease in solar radiation effect the efficiency of PTC. At various intervals, the reference receiver tube's heat absorption was monitored. The findings show a clear relationship between the quantity of heat received and solar radiation intensity. Over the course of the day, as solar energy reduces, so does the heat that the receiver tube absorbs. Figure 5.2 shows the heat absorbed against time visually represents this trend, showing a declining slope as the day goes on and solar radiation decreases.

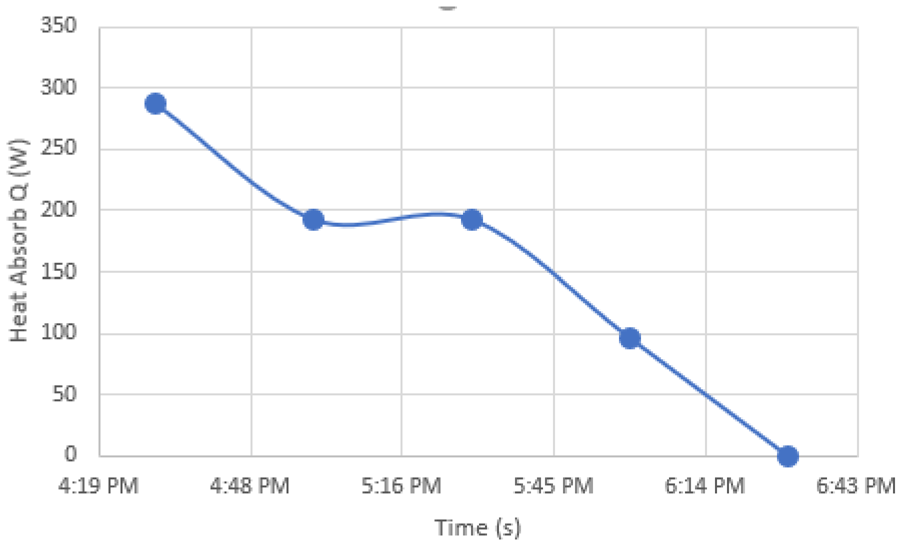


Figure 5.2: Variation of Q with the time of reference receiver tube

Figure 5.3 shows displays variations in the relationship between the tube's surface temperature and the temperature difference of outlet and inlet of reference receiver tube. The tube's surface temperature and the temperature difference between the inlet and outlet both drop with decreasing solar radiation. But the graph also displays variations in these numbers, which are probably caused by variables like changes in wind speed, solar intensity, or other environmental aspects.

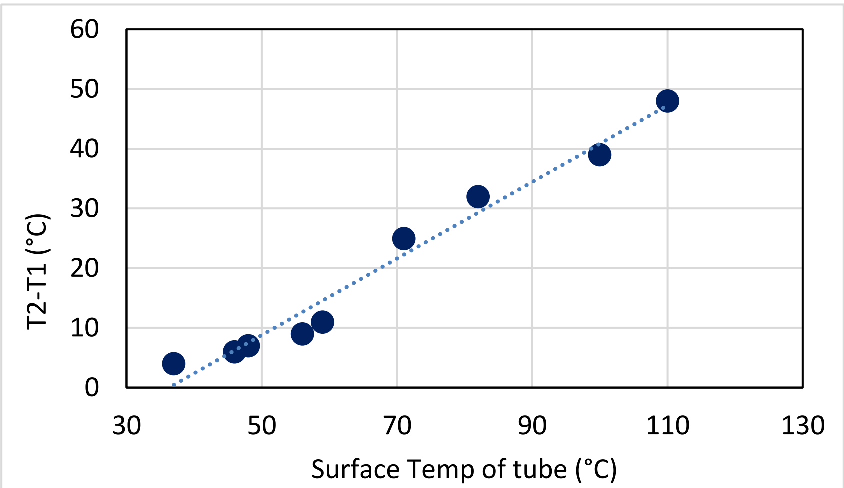


Figure 5.3: Variation b/w surface temperature & temperature difference of reference tube

Again, experiment was carried out at various times of the day, altering the flow rate of the heat transfer fluid (water) passing through the modified receiver tube integrated with phase change material (KNO3 & NaNO3), in order to evaluate the effect of flow rate on heat absorption. To find the quantity of heat absorbed by the system under various flow conditions, the gathered data was evaluated. The findings show a strong relationship between heat absorption and flow rate. The system's capacity to absorb and hold solar energy increased with flow rate. This is explained by the more effective heat transfer caused by the increased contact between the water and the heated receiver tube surface. Figure 5.4 shows the link between heat absorption and flow rate further supports the experimental findings. Higher flow rates are regularly associated with increased heat absorption, as the graph's positive linear trend suggests.

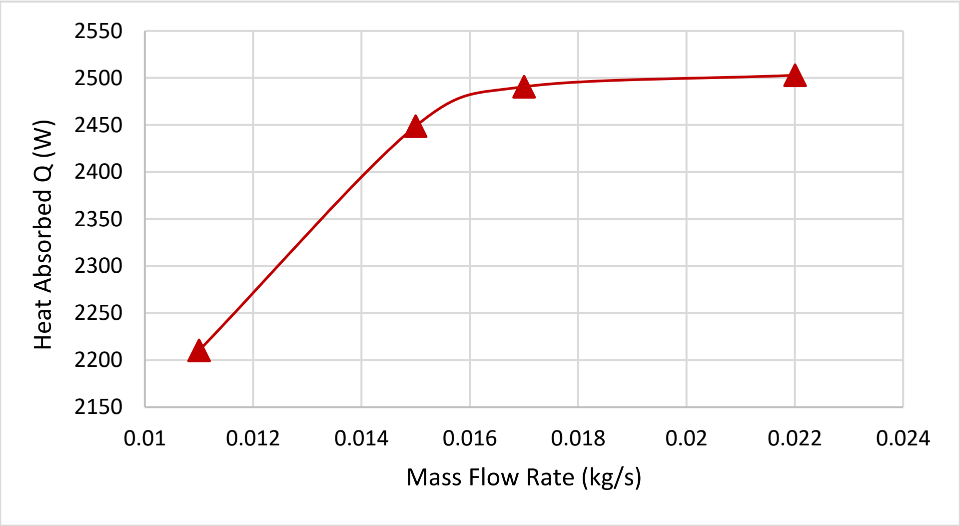


Figure 5.4: Variation of Q with the change of mass flow rate of modified receiver tube

The modified receiver tube's heat absorption was recorded at different intervals during the day, and the flow rate was kept constant to assess the effect of PCM (KNO3 & NaNO3) integration on heat absorption under varying solar radiation circumstances. There was a discernible drop in heat absorption in the evening as the sun's radiation progressively dropped. The link between time and heat absorption was then shown on a graph using the obtained data. The outcomes showed that, even as solar intensity decreased, the PCM integrated receiver tube efficiently absorbed and stored solar energy during moments of peak radiation, producing a more sustained heat production. The KNO3 and NaNO3 phase change properties, which enable it to absorb and release latent heat and so smooth out the oscillations in solar energy intake, are responsible for this increased heat retention capabilities.

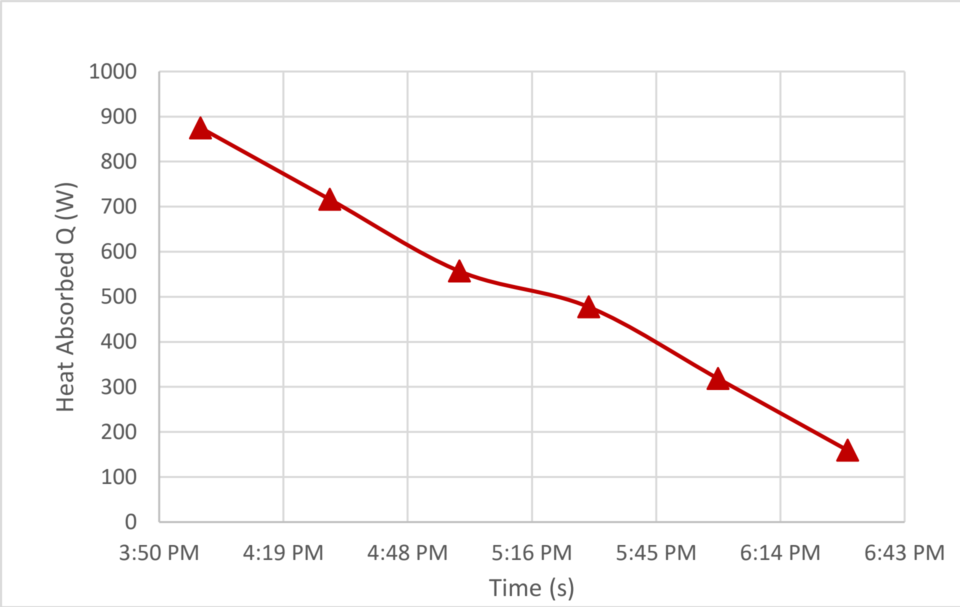


Figure 5.5: Variation of Q with the time of modified receiver tube

As solar radiation declines, the graph shows the link between the surface temperature of the modified tube integrated with PCM in a PTC and the temperature differential between its inlet and outlet. Both the tube's surface temperature and the differential in temperature between the entrance and outlet steadily decrease as sun radiation decreases. In contrast to a tube without phase change material (PCM), the temperature decrease is lessened because of PCM, creating a smoother and more stable temperature profile. The reason for this phenomenon is that the PCM is able to absorb surplus heat during high solar radiation periods and release it during low radiation periods. This allows the PCM to effectively buffer temperature swings and ensures that the PTC operates more consistently.

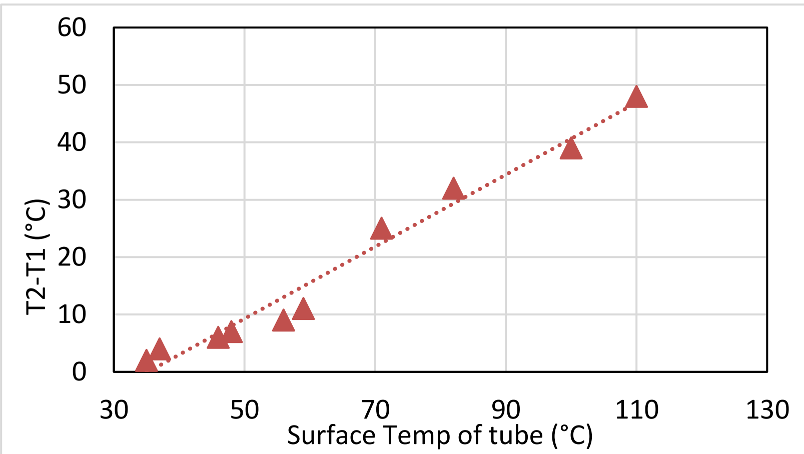


Figure 5.6: Variation b/w surface temperature & temperature difference of modified tube

COMPARISON

There is cleared evidence that both tubes exhibit different pattern of graphs when comparing the heat absorption, flow rate and temperature difference of outlet and inlet of reference receiver tube and modified receiver tube. This could be due to factor such as improve thermal insulation, a presence of phase change material and material of receiver tube. By comparing, it is computed that modified receiver tube is better than simple receiver tube.

Rate of drop: In comparison to the modified tube, the reference receiver tube shows a substantially steeper drop in heat absorption over time. This implies that the heat absorbing ability of the modified tube is degrading more quickly.

Energy Storage: The modified tube's PCM enables the storage of thermal energy, which can subsequently be released to produce heat even in the absence or at low levels of solar radiation. The system's overall dependability and energy efficiency are improved by this feature.

Decreased Fluctuations: By serving as a thermal buffer, the PCM lessens temperature swings brought on by differences in solar energy. Applications that need a steady heat supply will benefit from this stability.

Overall Performance: The receiver tube's performance appears to decline more quickly than the modified tube's, which suggests a possible problem or design error. The reference tube's heat absorption decreased gradually.

In summary, the PCM integrated modified receiver tube outperforms the reference receiver tube in terms of performance. Because of its capacity to store thermal energy and lessen fluctuations, it is a better option for applications requiring a dependable and effective solar thermal system.

Chapter 07

CONCLUSIONS

The goal of this senior project was to improve parabolic trough collectors (PTC) by incorporating phase change material (PCM). By reducing the impact of variable solar radiation and facilitating thermal energy storage, the main goal was to increase the collector's thermal performance. First, a reference tube was constructed and tested in order to accomplish this. Afterwards, the tube underwent alterations with the addition of a PCM layer. Experiments were carried out with different flow rates and durations, with special focus on how well the system performed when solar radiation was declining. In comparison to the reference tube, the modified PTC with the PCM showed significantly better heat absorption capacities, as the experiment results clearly showed. By efficiently storing thermal energy, the PCM lessened the effects of varying solar radiation and guaranteed a more consistent heat output. Improved thermal performance is essential for applications that need a steady and dependable source of heat energy.

The PTC's incorporation of PCM has a number of noteworthy benefits. First of all, during times of strong solar radiation, the PCM serves as a thermal energy storage medium, enabling the capture and preservation of excess heat. To ensure a steady supply of heat, this stored energy can subsequently be released at night or during times when solar radiation is low. Second, the PCM contributes to a more steady and consistent heat output by reducing the impacts of variable solar radiation. Two PCMs that showed promise among the several that were examined for this study were potassium nitrate (KNO_3) and sodium nitrate ($NaNO_3$). These salts are appropriate for usage in PTCs because they have a number of advantageous characteristics. Due to their large latent temperatures of fusion, KNO_3 and $NaNO_3$ can both absorb and release a sizable quantity of thermal energy during the phase transition. Furthermore, these PCMs maintain their solid state under the majority of operating situations thanks to their comparatively high melting points. Furthermore, the effective passage of heat between the PCM and the receiver tube is facilitated by the high thermal conductivity of both KNO_3 and $NaNO_3$.

In conclusion, a major development in solar thermal technology has been made with the incorporation of PCM into parabolic trough collectors. PCM-integrated PTCs provide a more dependable and effective solution for a range of applications by improving thermal performance, reducing the effects of variable solar radiation, and enabling thermal energy storage. The usefulness and efficacy of this technique are further increased by the use of PCMs like KNO_3 and $NaNO_3$.

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