DESIGN AND ANALYSIS OF PARABOLIC THROUGH COLLECTOR

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Abstract:
Parabolic trough collectors (PTCs) are a well-tested solar concentrating technology with many different uses. To become a mainstream technology, they need to have their performance boosted significantly. Adding challenges on the inside of the collector could be a promising strategy for boosting its efficiency. Without a way to dissipate the solar thermal energy, the collector receiver heat loss must be equal to the amount of energy collected. This will concentrate on thermal and CFD analysis utilizing various fluids, including air, water, and various solar collectors, including flat plates and parabolic troughs, which were modeled using NX 12.0 design software. Thermal study was conducted on a solar collector made of a variety of materials. Moreover, CFD analysis to identify the temperature and CFD analysis to calculate the Pressure, Temperature and Velocities with different materials.
Keywords: Parabolic trough collectors, NX 12.0, CFD

1.0 INTRODUCTION

Many sectors face the challenge of rising energy consumption and diminishing energy supplies. Estimating the importance of the energy needed for various processes has only been attempted by a few researchers. This experimental study explores potential uses of solar energy outside traditional applications. Solar energy, which is a form of radiant energy with a high temperature and exergy, has many advantages over other forms of renewable power. It is a strong and dependable renewable resource that can be used domestically and has a lot of untapped potential. It also produces almost no of the glasshouse gases that are becoming an increasing problem. The development of a parabolic trough solar water heater was completed. The process followed entails steps like creating a blueprint and then building and testing the product. The curved mirror reflector surface, support structure, absorber pipe, and equipment platform were all fabricated on-site. Here, we highlight a solar water heating system with optical focusing technologies as a significant newcomer to the market for supplying the necessary bulk solar energy, in addition to a reusable parabolic trough solar water heater as a viable renewable technology for reducing water-heating expenses.

Parabolic Trough Collector:

- To focus the sun's beams on the reception tube, the parabola trough uses a series of concave mirrors. These valleys can rotate around a single axis, usually north to south, to follow the

Sun and maximise efficiency. This tube absorbs concentrated solar energy, which is used to heat the fluid as it travels through it.

- To reduce the extreme temperatures generated by the mirrors, a synthetic oil or molten salt mixture is often circulated via the heat exchanger tubes. The typical temperature range for heating this fluid is between 400–600∘C. Once the oil is in the tubes, the procedure can proceed.

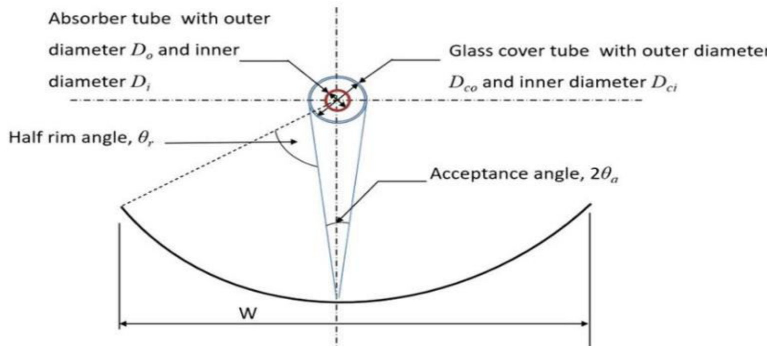

Figure 1: Diagram of Solar Parabolic Trough Collector

Primary Parts of a Parabolic Trough Collector

In order to better understand how a parabolic collector works, keep reading. A parabolic trough consists of the following components:

1. **Parabolic Trough Reflector**: The collector's lens is located here. By reflecting the sunlight, it sends the signal to the receiving tube below. Silver and aluminium are the two most often used reflective materials, and they are frequently put on a glass base.
2. **Receiving tube or absorber**: This apparatus uses the thermal energy of concentrated light to heat a fluid. It provides a limited set of features in order to optimise the efficiency of energy conversion.
3. **Tracking devices and Transmission system**: Collectors rotate such that the sun's rays enter from the direction they came from. Tracking equipment is used to fine-tune and focus the collection as the sun moves throughout the day.
4. **Operating fluid**: Many solar-powered systems use thermal oil as their principal fluid for transferring heat. However, other chemicals, such as water or steam, can be used instead. This fluid supplies the thermal energy that boils the water to produce steam. The steam then assists the turbine in functioning, which produces energy.

Objectives:

- To study the parabolic through Collector with different Applications
- To design PHC using NX 12.0 and the analysis was done by using ANSYS 2022 R1 with different materials at various Temperatures
- The CFD Analysis was done by using air and water to determine the pressure, Velocity and temperatures

2.0 LITERATURE REVIEW

Madan [1] Designed and produced a solar-powered cylindrical water warmer. High-quality glass was rolled into a cylinder, and a copper coil tube with spiralling rings painted black acted as a collector for the sun's rays striking the glass. It was found through analysis to be financially beneficial to use a cylindrical solar water heater instead of a flat plate collector. **Helal et al [2].** established the geometrical features of an integrated collector stack (ICS) with a single horizontal cylinder tank housed in a reflector with three parabolic arms. This setup was compared to two other solar water heating systems: one with an asymmetric CPC tank and the other with a symmetric CPC tank. **[3] Mohammed** developed a parabolic dish solar water heater for use in heating water for household use. An automatic electrical control circuit was created to ensure the design's optimal functionality. The water heater only heats up to roughly 10 litres at a time so as to conserve valuable floor space. Instead of using a manually operated tracking mechanism, an automatic linear actuator (Super Jack) was selected. **Pei et.al [4].** A series of tests were conducted in Hefei, China, to determine the efficacy of using a mini-CPC reflector in conjunction with an evacuated tube solar water heating system. In order to compare and contrast their thermal performance, the first and second laws of thermodynamics were applied. Data was collected for two days to examine the performance of two different solar water heating systems. **Singh et al [5].** investigated the feasibility of producing hot water using solar thermal technology. The parabolic trough concentrator (PTSC) consisted of an aluminium sheet wrapped in cloth to which rectangular mirror strips were bonded. Two different absorber tubes were used to evaluate the PTSC's performance without the glass cover. **Oggy Et.al [6].** constructed a solar water heater using off-the-shelf materials for a home. The solar energy is absorbed by a flat-plate collector, which consists of an absorber plate, a grid of fluid-carrying tubes underneath, an insulated covering with a see-through glass cover, and an integrated cold and hot water tank. **Pachkawade Et.al [7].** The cost and size of a solar water heater can be reduced by substituting less expensive and more easily accessible materials, such as plastic lateral tubes, HDPE pipe, old glass wool, thermocol, plastic barrel,G.I. sheet collect or boxes, for more expensive and less easily accessible alternatives. The use of " Pebbles " as a medium of heat storage in a solar water heater allows for increased capacity without the use of power. **Macedo- Valencia et.al [8].** presented an article that discussed the process of developing a parabolic trough collector (PTC) to heat water as a proof-of-concept model. The design was created with the help of CAD/CAM software. In order to determine the flow rate, water is poured from the container, heated in an absorber pipe, and then collected in a glass baker. **Khan et.al [9]** An innovative solar thermal heat pump system based on a loop of heat pipes has been designed to meet the demand for domestically-sized amounts of hot water. In preparation for an experimental study, they created a prototype solar water heating system. **Zou and Dong et.al [10]** In order to heat water in frigid climates, an experimental dissertation was written on the topic of miniature parabolic trough solar collectors. At fluid temperatures below 100 °C, the suggested PTC showed its greatest thermal performance, and this effectiveness increased as the fluid increased in temperature.

3.0 METHODOLOGY

The collectors designed as parabolic troughs focus sunlight in a single direction, called the focal line. These collectors see widespread industrial use for producing electricity. The solar array accounts for about 37% of the entire price tag. An important step towards making solar thermal power plants financially viable is decreasing the price of solar thermal collectors. The concentrator has a concave shape and works like a parabolic mirror. It takes in light from the sun and sends a reflection back down the line of focus. Along the axis of convergence, a receiver made up of a stainless-steel tube lined with glass sits. The absorber tube takes in the concentrated solar heat from the concentrators and transmits it to a heat-retaining fluid.

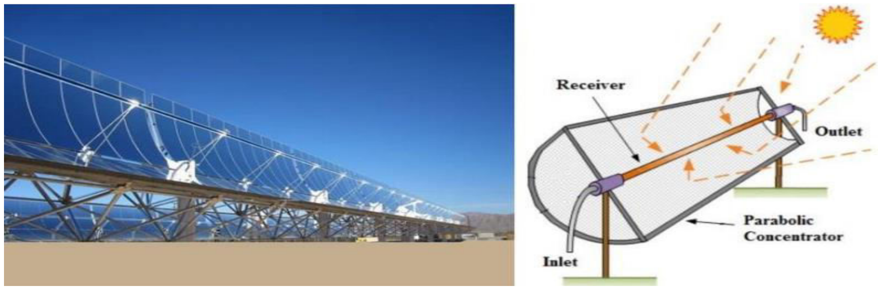

Figure 2: Parabolic Trough Collector

- Heat transfer within a water-flowing pipe is the focus of this investigation into a parabolic solar collector. In the current configuration, a solar panel is placed on top of a water pipe.
- A parabolic plate serves as the solar radiation absorber plate, located behind the tube to collect and concentrate the sun's rays for later use. Parabolic solar collectors work in this way.
- To reflect this, the wall of the flow pipe is segmented into an upper and lower section. The sun warms the upper portion of the wall as it rises.
- However, the parabolic absorber plates of the collector affect the lower part of the wall.

INTRODUCTION TO NX 12.0

NX 12 improves productivity by allowing users to do more with less effort during the editing and creative processes. When adding, removing, or modifying a feature, for instance, you will now see a new column displaying the section's orientation. When removing a feature, you may now choose whether or not to also remove any of its child features.

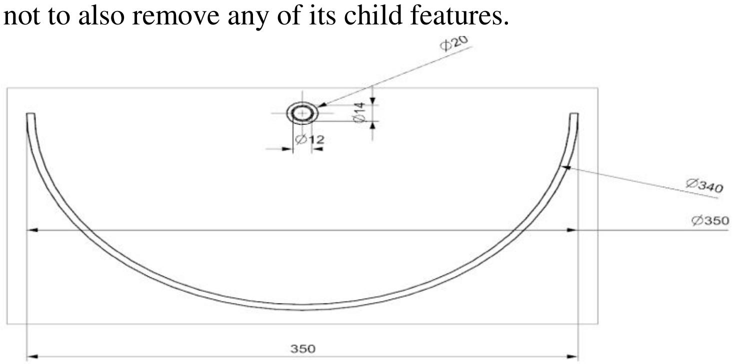

Figure 3: Reflected geometric view

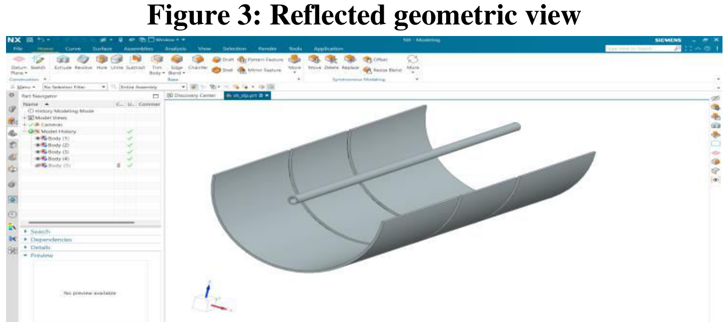

Figure 4: NX 12.0 Model

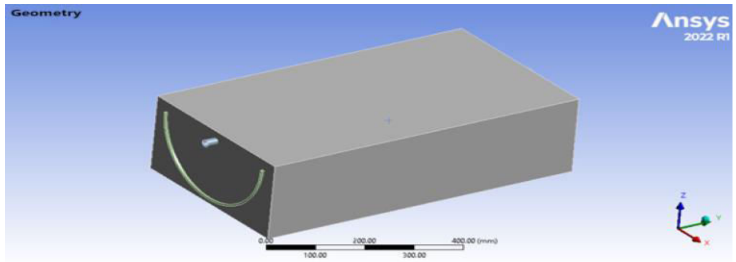

Figure 5: Imported model

The model is designed with the help of NX 12.0 and then import on ANSYS to analyze the thermal analysis and determine the temperature variations

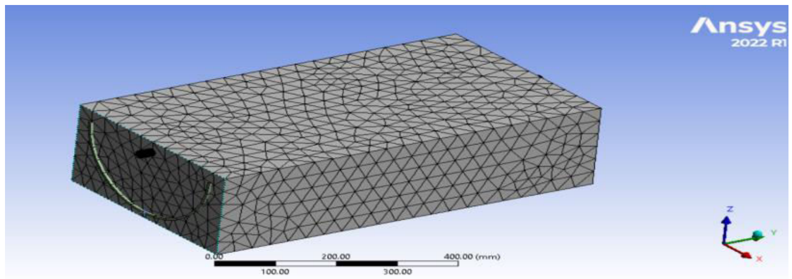

Figure 6: Meshed model

The model is designed with the help of NX 12.0 and then import on ANSYS for Meshing and analysis. The analysis by fluid analysis is used in order to calculating temperature, pressure and velocity. A tetrahedral structure mesh is used So, the total number of nodes and elements is 38127 and 143776

Materials- Tube using Copper Alloy

Tube- copper

Collector- AL alloy, Bronze, Glass panel

Velocity:

Fluid -water

V-0.5m/s pressure- 1.6 bar

Reflector temperature-40, 44, 47 degrees

Radiation temperature-32

Time initialization- 3 seconds

Initial temperature-24^{0}C

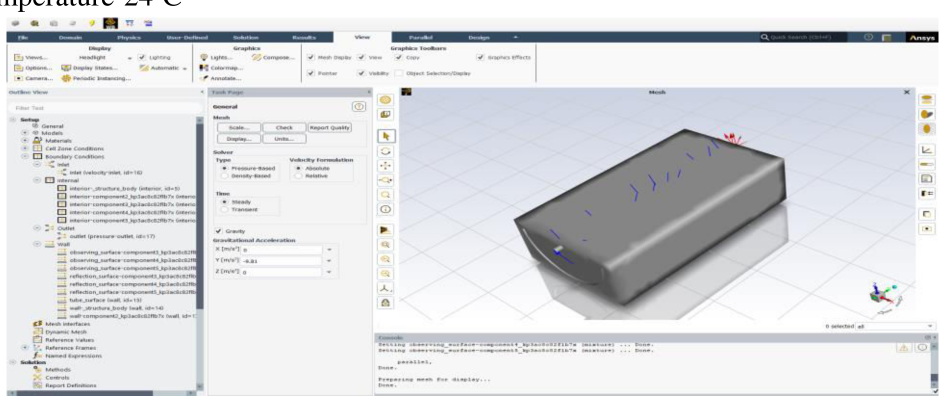

Figure 7: Initial boundary conditions

4.0 RESULTS AND DISCUSSIONS

In their study to parabolic trough solar collectors, there have been insufficient studies to determine three-dimensional temperature distributions. To further understand the temperature distribution, we investigate the impact of continuous solar radiation on a parabolic trough collector. The simulations are executed using ANSYS 2022R1.

Transient thermal Analysis:

Transient thermal analysis is the study of how a system reacts over time to both constant and changing boundary conditions. It is possible to calculate the time required to obtain a steady state temperature under constant boundary conditions, as well as the maximum period that operating circumstances can be maintained until a critical temperature is reached.

Transient thermal analysis Using bronze material PTC at 40^{0}C:

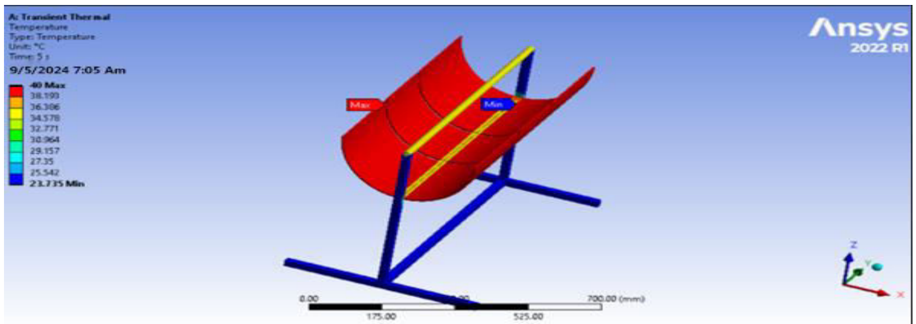

Figure 8: Temperature

The simulation of the Parabolic through collector is done during the study and the results obtained are discussed in the following section. The maximum receiver surface is found to be 40^{0}C temperature remains constant and middle of the Aluminum tube was slide reflected the heat at PTC surface

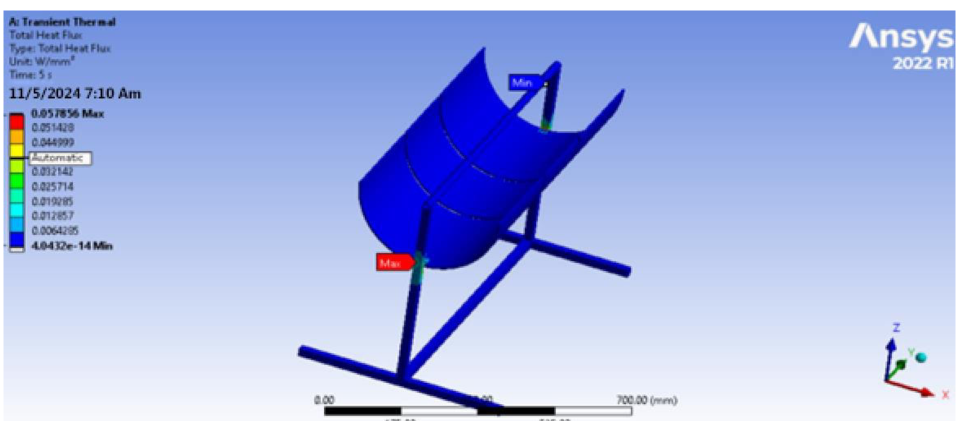

Figure 9: Total heat flux

The figure shows the Total heat flux variation across the receiver and the collector surface. The maximum receiver surface is found to be 5.7856e-002. the absorber while the collector surface found to 40^{0}C temperature remains constant.

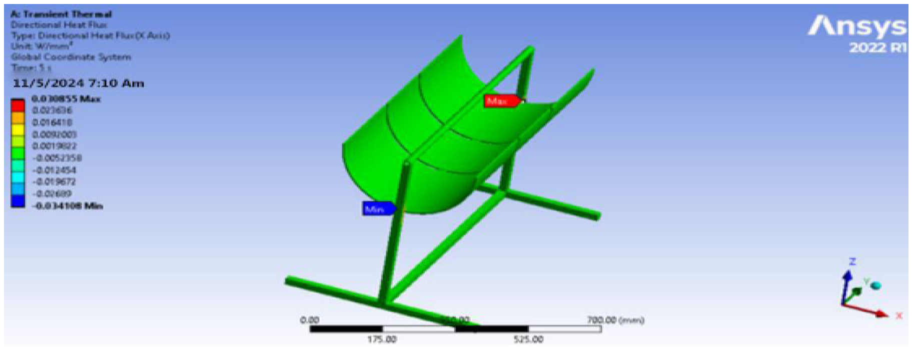

Figure 10: Directional heat flux

The figure shows the Directional heat flux variation across the receiver and the collector surface. The maximum receiver surface is found to be 3.0855e-002. the absorber while the collector surface found to 40^0C temperature remains constant.

Transient thermal analysis Using bronze material PTC at 44^0C:

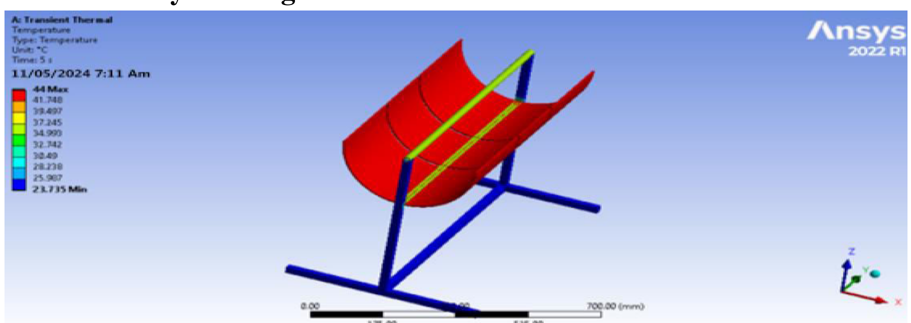

Figure 11: Temperature

The simulation of the Parabolic through collector is done during the study and the results obtained are discussed in the following section. The figure shows the temperature variation across the receiver and the collector surface. The maximum receiver surface is found to be 44 ^{0}C temperature remains constant.

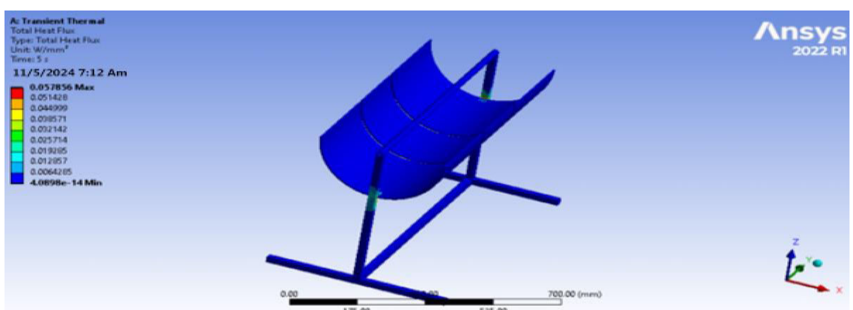

Figure 12: Total heat flux

The figure shows the Total heat flux variation across the receiver and the collector surface. The maximum receiver surface is found to be 5.7856e-002. the absorber while the collector surface found to 44^0C temperature remains constant.

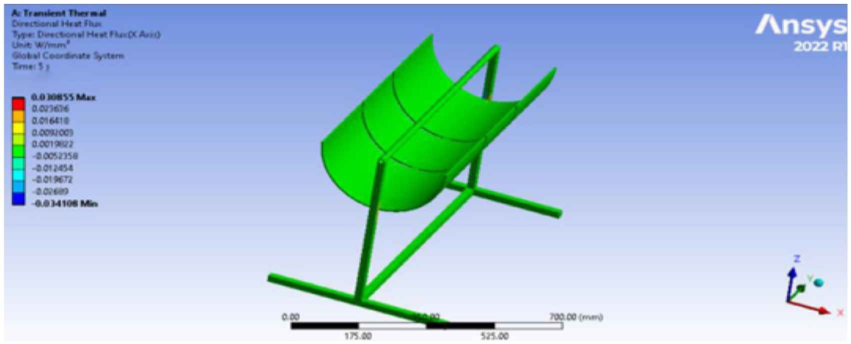

Figure 13: Directional heat flux

The figure shows the Directional heat flux variation across the receiver and the collector surface. The maximum receiver surface is found to be 3.0855e-002. the absorber while the collector surface found to 44^{0}C temperature remains constant.

Transient thermal analysis Using bronze material PTC at 47^{0}C:

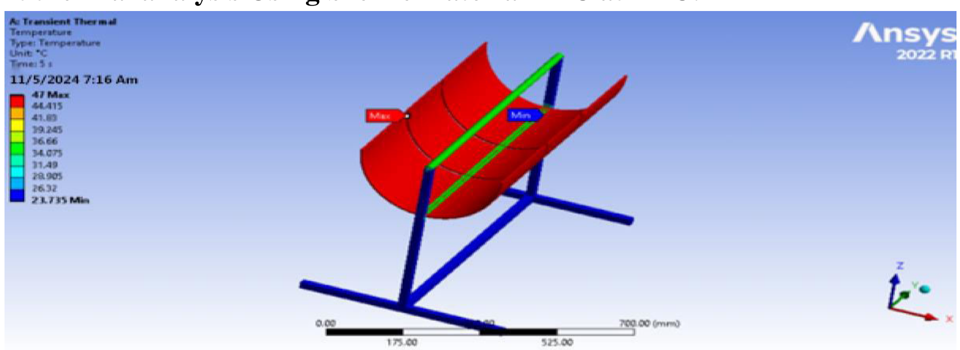

Figure 14: Temperature

The simulation of the Parabolic through collector is done during the study and the results obtained are discussed in the following section. The figure shows the temperature variation across the receiver and the collector surface. The maximum receiver surface is found to be 40 ^{0}C temperature remains constant and middle of the Aluminum tube was slide reflected the heat at PTC surface

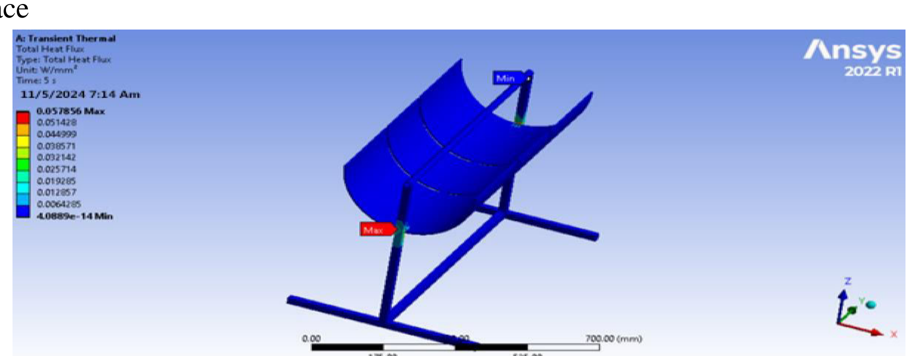

Figure 15: Total heat flux

The figure shows the Total heat flux variation across the receiver and the collector surface. The maximum receiver surface is found to be 5.7856e-002. the absorber while the collector surface found to 47^{0}C temperature constant.

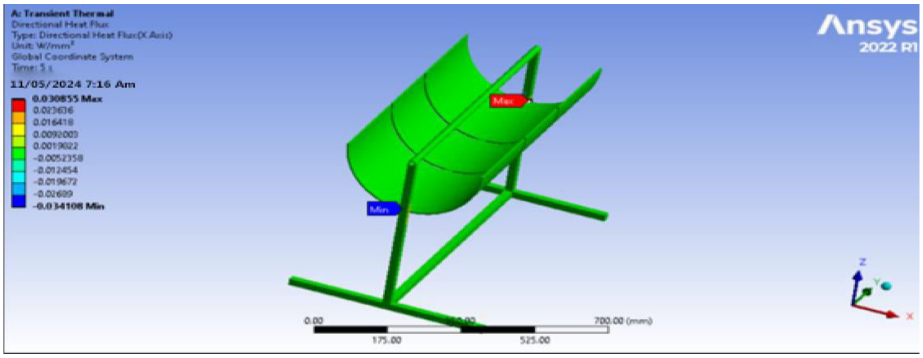

Figure 16: Directional heat flux

The figure shows the Directional heat flux variation across the receiver and the collector surface. The maximum receiver surface is found to be 3.0855e-002. the absorber while the collector surface found to 47^{0}C temperature remains constant.

Transient Thermal analysis PTC using Copper alloy at 40^{0}C:

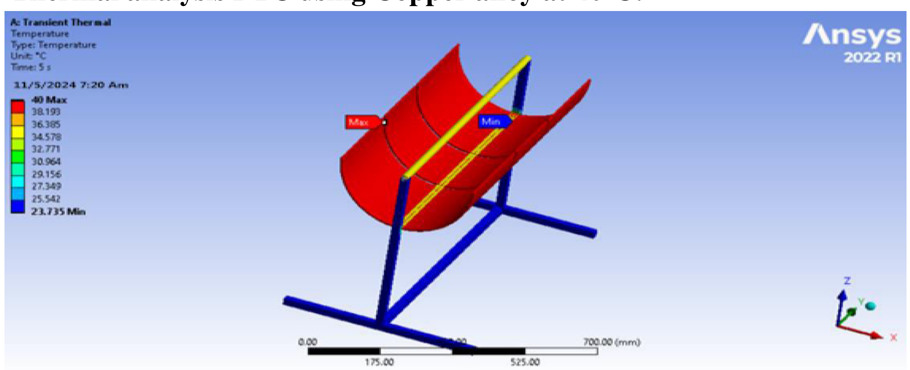

Figure 17: Temperature

The figure shows the Copper alloy PTC parameter Temperature maximum receiver surface found to 40^{0}C and middle of the Aluminum tube was slide reflected the heat at PTC surface

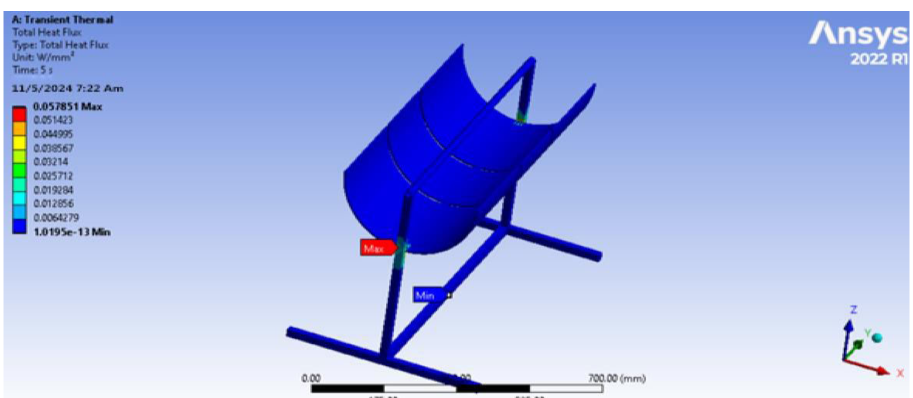

Figure 18: Total heat flux

The figure shows the Copper alloy PTC parameter Total heat flux maximum receiver surface is found to be 5.7851e-002. To absorber the collector surface found to 40^{0}C temperature remains constant.

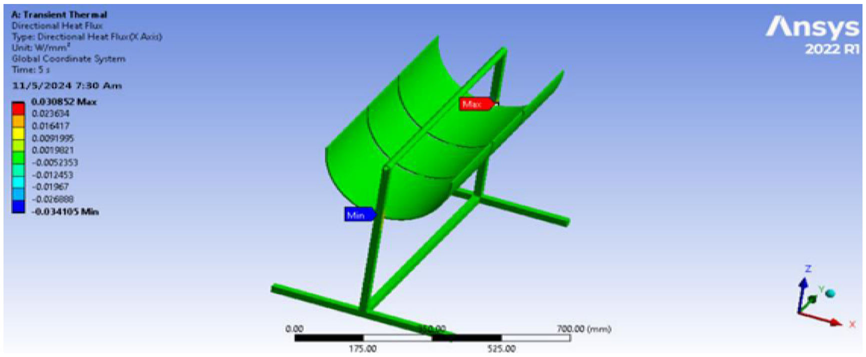

Figure 19: Directional heat flux

The figure shows the Copper alloy PTC parameter Directional heat flux maximum receiver surface is found to be 3.0852e-002. the absorber while the collector surface found to 40^0C temperature remains constant.

Transient Thermal analysis PTC using Copper alloy at 44^0C

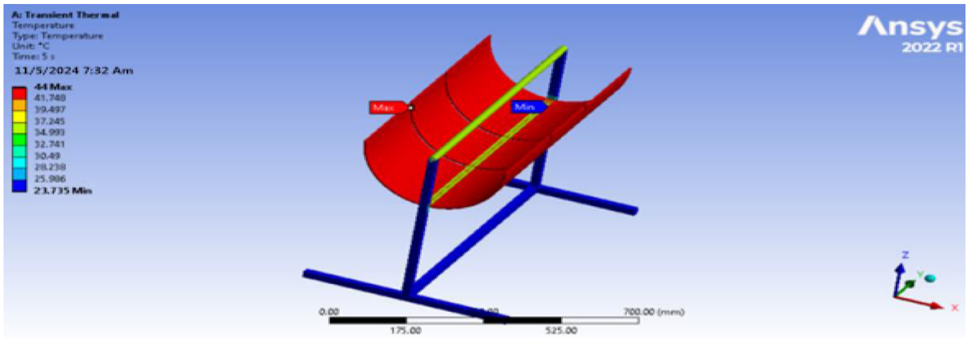

Figure 20: Temperature

The figure shows the Copper alloy PTC parameter Temperature maximum receiver surface found to 44^0C and middle of the Aluminum tube was slide reflected the heat at PTC surface

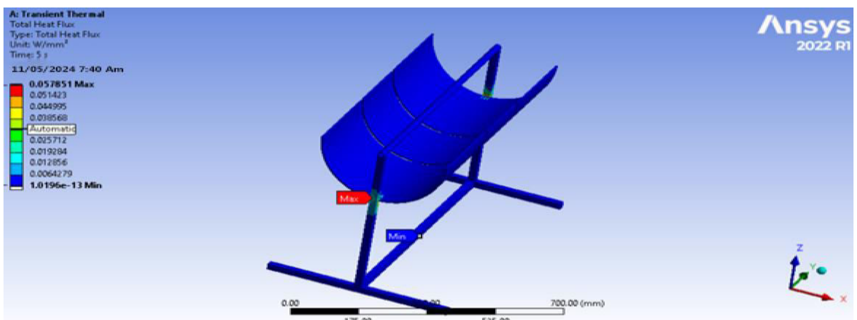

Figure 21: Total heat flux

The figure shows the Copper alloy PTC parameter Total heat flux maximum receiver surface is found to be 5.7851e-002. To absorber the collector surface found to 44^0C temperature remains constant.

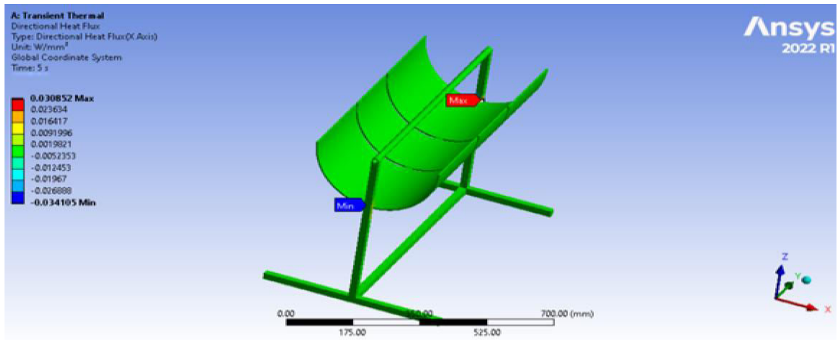

Figure 22: Directional heat flux

The figure shows the Copper alloy PTC parameter Directional heat flux maximum receiver surface is found to be 3.0852e-002 the absorber while the collector surface found to 44^{0}C temperature remains constant.

Transient Thermal analysis PTC using Copper alloy at 47^{0}C

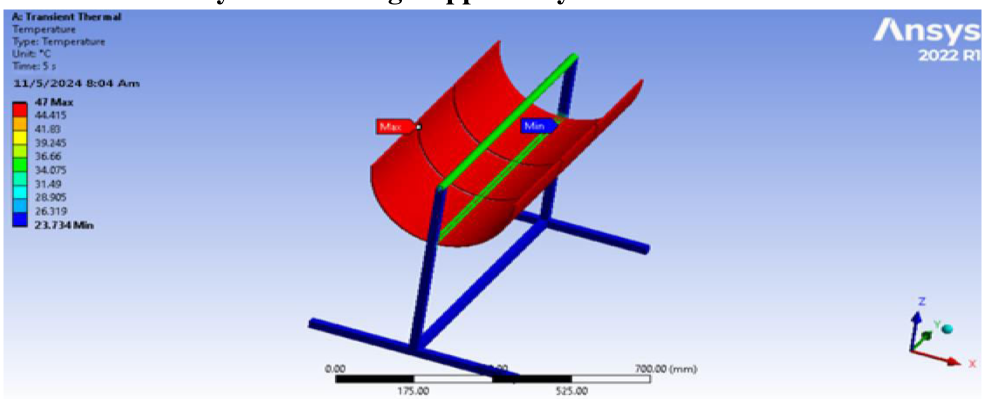

Figure 23: Temperature

The figure shows the Copper alloy PTC parameter Temperature maximum receiver surface found to 47^{0}C and middle of the Aluminum tube was slide reflected the heat at PTC surface

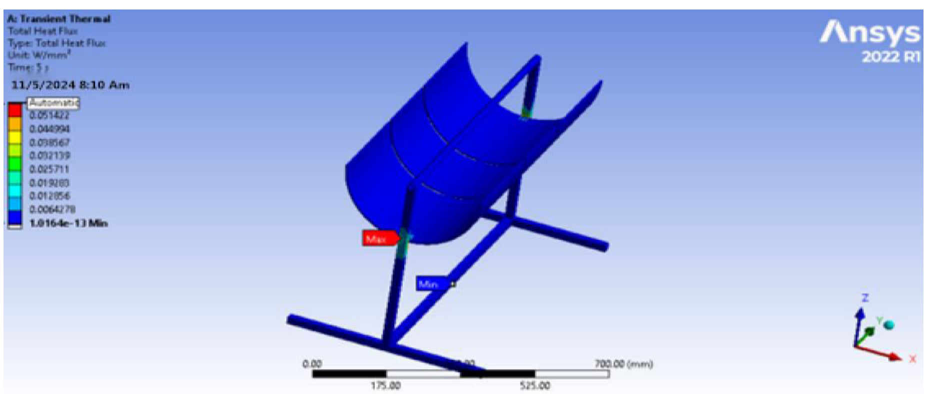

Figure 24: Total heat flux

The figure shows the Copper alloy PTC parameter Total heat flux maximum receiver surface is found to be 5.7851e-002. To absorber the collector surface found to 47^{0}C temperature remains constant.

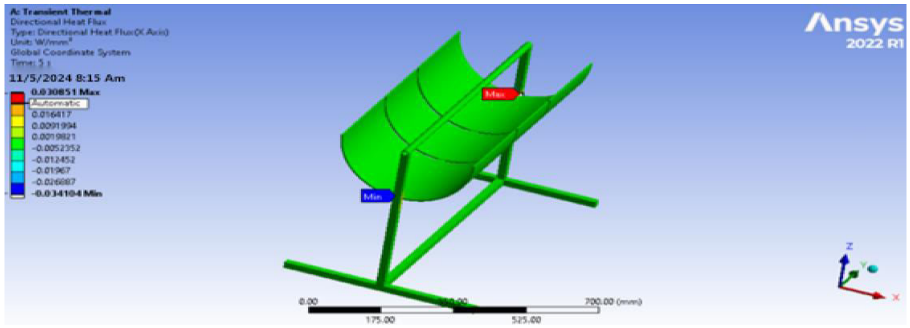

Figure 25: Directional heat flux

The figure shows the Copper alloy PTC parameter Directional heat flux maximum receiver surface is found to be 3.0852e-002 the absorber while the collector surface found to 47^{0}C temperature remains constant.

Transient Thermal analysis PTC using Glass panel at 40^{0}C:

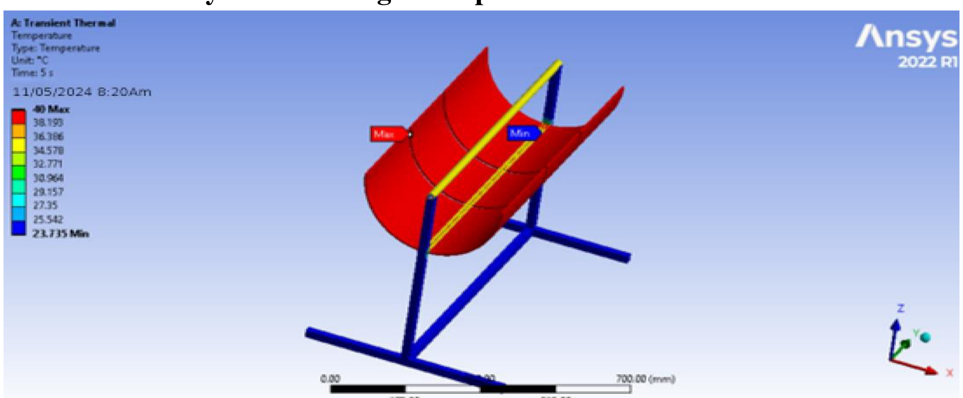

Figure 26: Temperature

The figure shows the Glass panel PTC parameter Temperature maximum receiver surface found to 40^{0}C and middle of the copper tube was slide reflected the heat at PTC surface

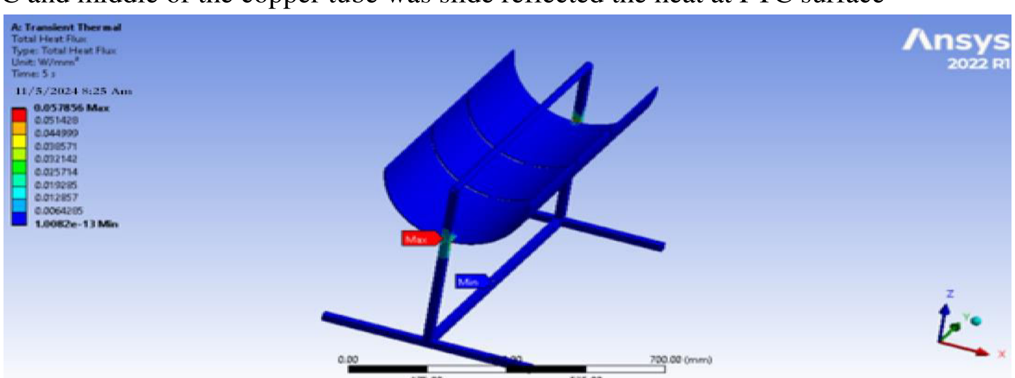

Figure 27: Total heat flux

The figure shows the Glass panel PTC parameter Total heat flux maximum receiver surface is found to be 5.7856e-002. To absorber the collector surface found to 40^{0}C temperature remains constant.

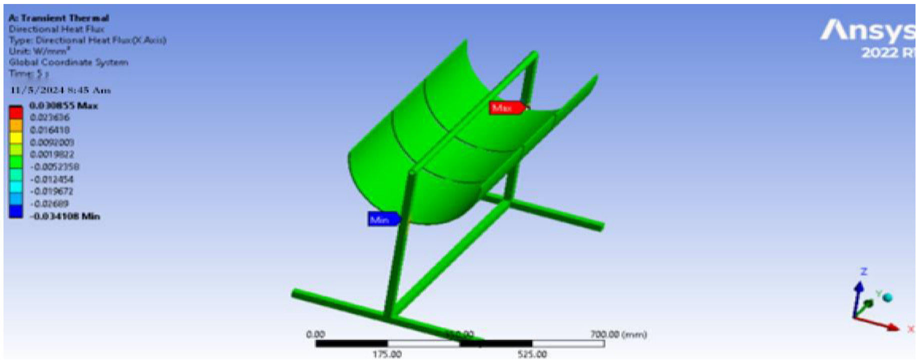

Figure 28: Directional heat flux

The figure shows the glass panel PTC parameter Directional heat flux maximum receiver surface is found to be 3.0855 max. the absorber while the collector surface found to 40^{0}C temperature remains constant.

Transient Thermal analysis PTC using glass panel at 44^{0}C

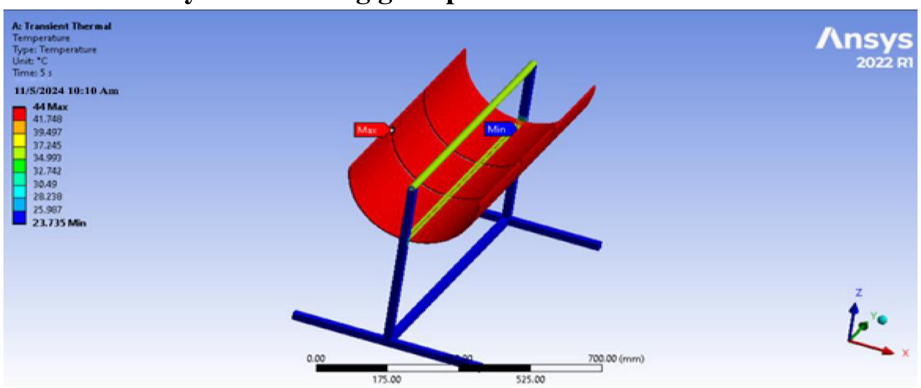

Figure 29: Temperature

The figure shows the glass panel PTC parameter Temperature maximum receiver surface found to 44^{0}C and middle of the copper tube was slide reflected the heat at PTC surface

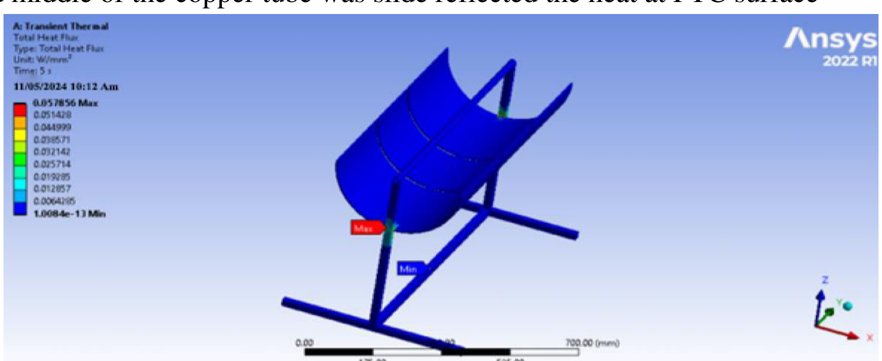

Figure 30: Total heat flux

The figure shows the glass panel PTC parameter Total heat flux maximum receiver surface is found to be 5.7851e-002. To absorber the collector surface found to 44^{0}C temperature remains constant.

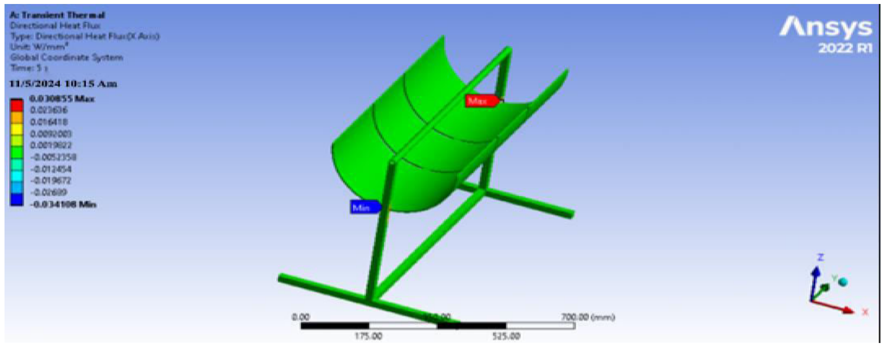

Figure 31: Directional heat flux

The figure shows the glass panel PTC parameter Directional heat flux maximum receiver surface is found to be 3.0852e-002 the absorber while the collector surface found to 44^{0}C temperature remains constant.

Transient Thermal analysis PTC using glass panel at 47^{0}C

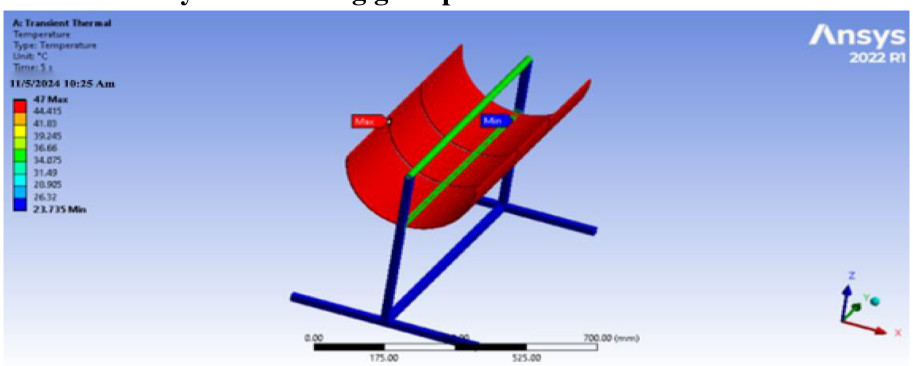

Figure 32: Temperature

The figure shows the glass panel PTC parameter Temperature maximum receiver surface found to 47^{0}C and middle of the copper tube was slide reflected the heat at PTC surface

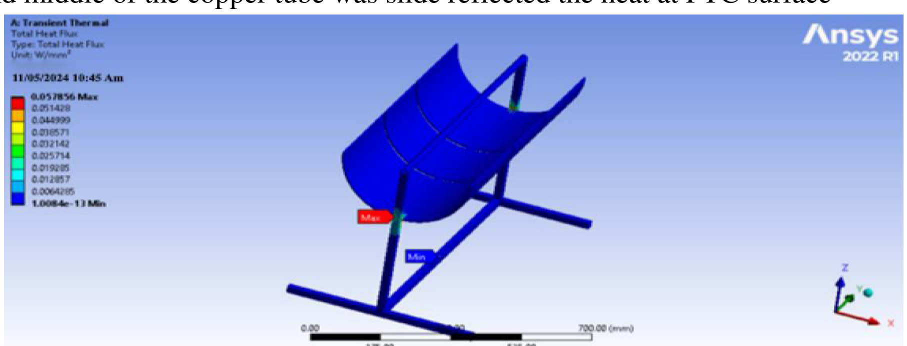

Figure 33: Total heat flux

The figure shows the glass panel PTC parameter Total heat flux maximum receiver surface is found to be 5.7851e-002. To absorber the collector surface found to 47^{0}C temperature remains constant.

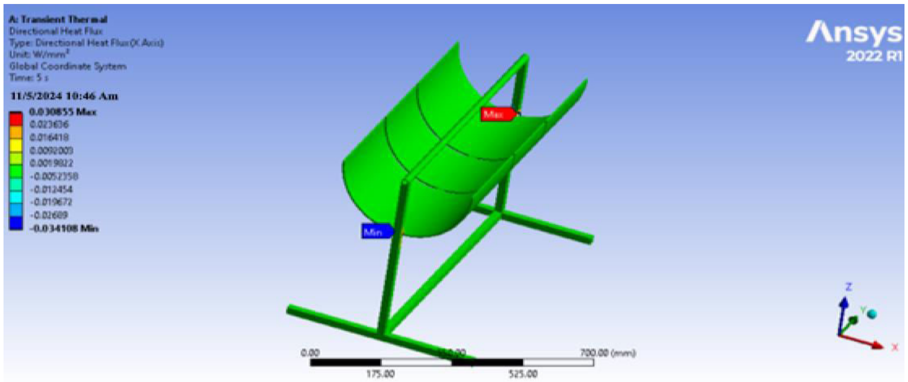

Figure 34: Directional heat flux

The figure shows the Copper alloy PTC parameter Directional heat flux maximum receiver surface is found to be 3.0852e-002 the absorber while the collector surface found to 47^{0}C temperature remains constant.

Table 1: PTC Maximum temperature variation at glass panel material

Parameters	**40^{0}C**	**44^{0}C**	**47^{0}C**
Temperature (0^{0}C)	40	44	47
Total heat flux(W/mm^2)	5.7856e-002	5.785e-002	5.785e-002
Directional heat flux(W/mm^2)	3.0855e-002	3.0852e-002	3.0851e-002

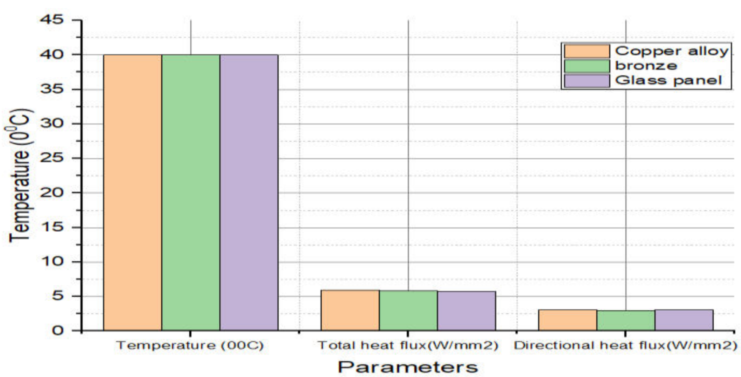

Figure 35: PTC Maximum temperature variation at 40^{0}C at different materials

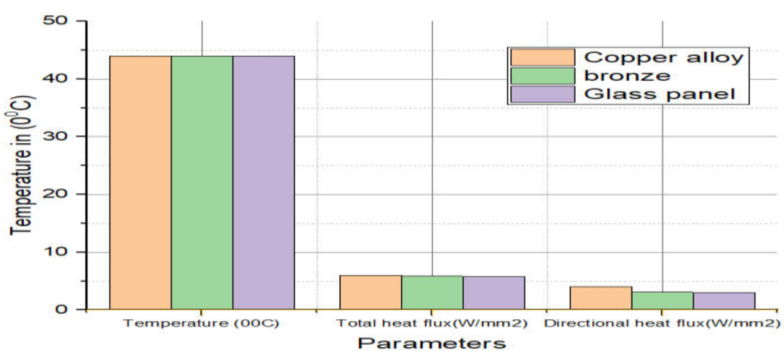

Figure 36: PTC Maximum temperature variation at 44^{0}C at different materials

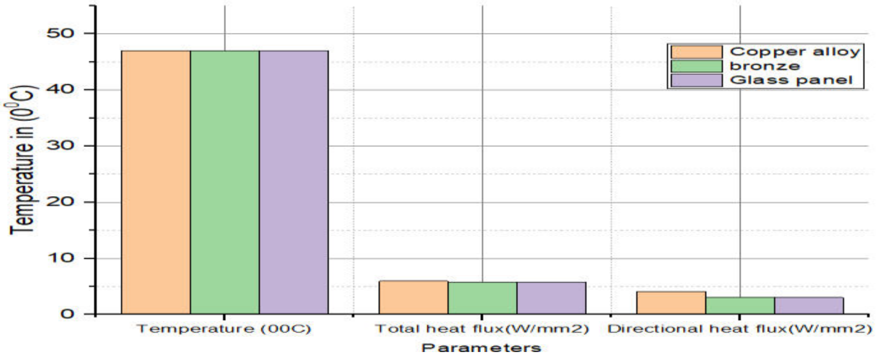

Figure 37: PTC Maximum temperature variation at 47^{0}C at different materials

CFD ANALYSIS OF SOLAR THROUGH PRABOLIC COLLECTOR:

When it comes to solving complex engineering and environmental challenges, computational fluid dynamics (CFD) is an effective method of numerical analysis. Optimization of designs is accomplished through the use of this simulation method, which models and predicts different heat, mass, and momentum transfer and fluid flow problems through the use of numerical equations and digital computers for iterative processes.

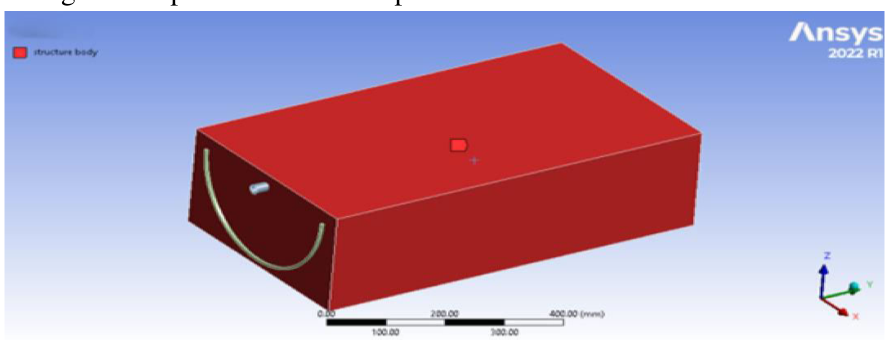

Figure 38: PHC Structural body

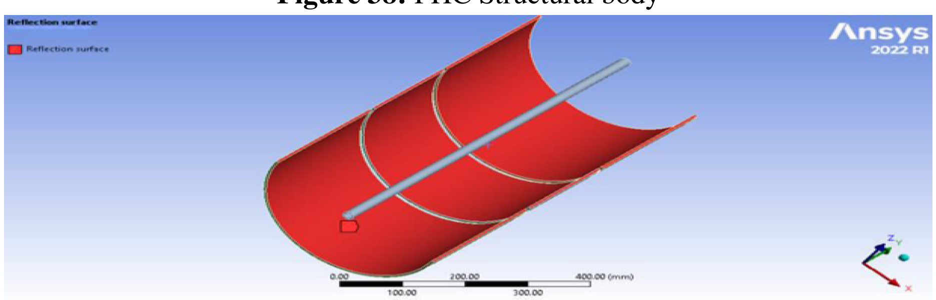

Figure 39: reflection Surface

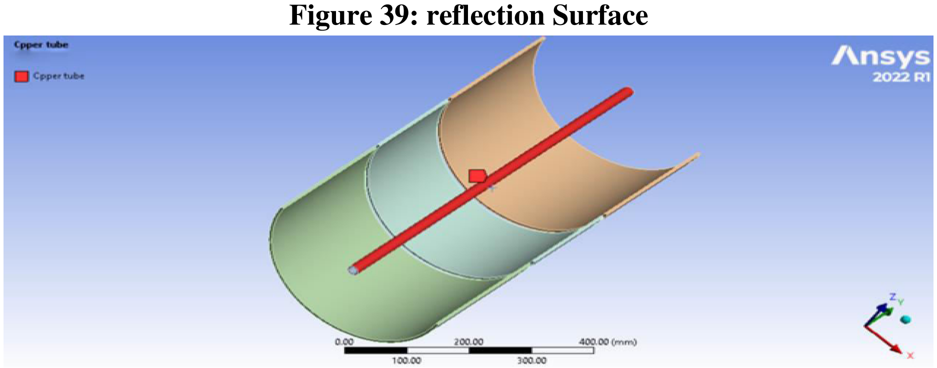

Figure 40: Copper tube

Case-1 (AL alloy as Reflector CFD Analysis at different Temperatures

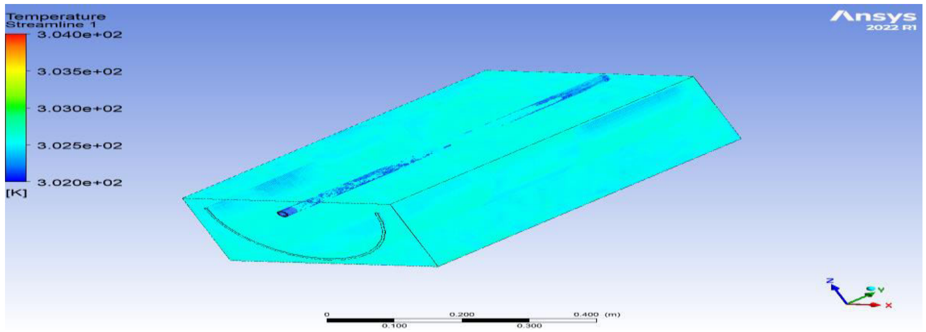

Figure 41: Temperature stream line at 304[K]

The figure shows the temperature variation of the receiver surface along the length from inlet to outlet. The maximum temperature of the pipe is found to be 304 [K] for a long length towards the water outlet for a mass flow rate of 0.25 kg/hr. It can be seen that the temperature of the pipe surface is found to increase along the length of the pipe.

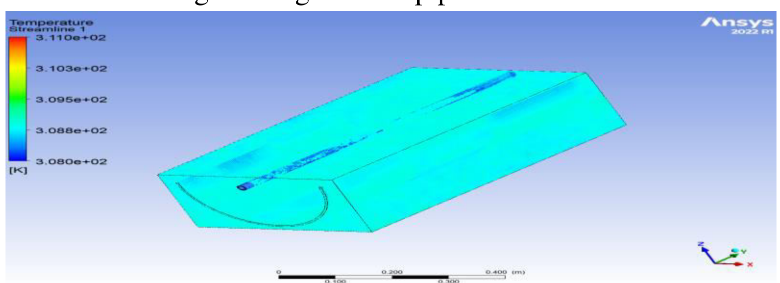

Figure 42: Temperature stream line at 311[K]

The simulation of the Parabolic through collector is done during the study and the results obtained are discussed in the following section. The figure shows the temperature variation across the receiver and the collector surface. The maximum receiver surface is found to be 311 [K] near the water outlet region of the absorber while the collector surface found to remains at constant temperature

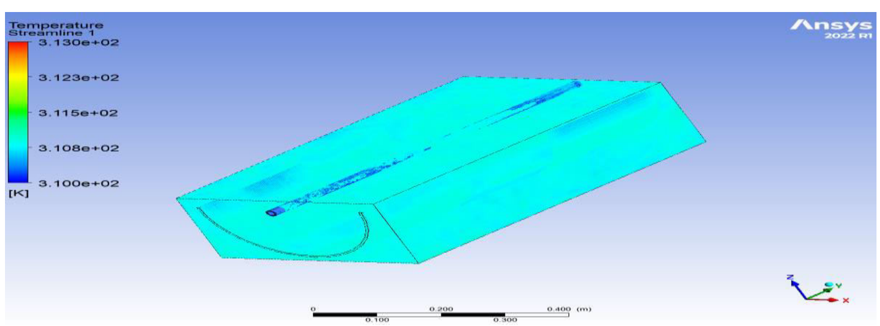

Figure 43: Temperature stream line at 313 [K]

The following section discusses the results obtained from a simulation of the Parabolic through collector. The figure shows the temperature variation across the receiver and the collector surface. A maximum of 313 [k] is observed at the receiver surface near the water outlet area of the absorber, while the collector surface remains constant.

Table 2: Different Temperatures using Parabolic through collector at various materials

Materials	Different Temperatures using Parabolic through collector		
Aluminum Alloy	**304**	**311**	**313**
Bronze	**305.2**	**312.6**	**314.1**
Glass panel	**307.6**	**314.2**	**317.5**

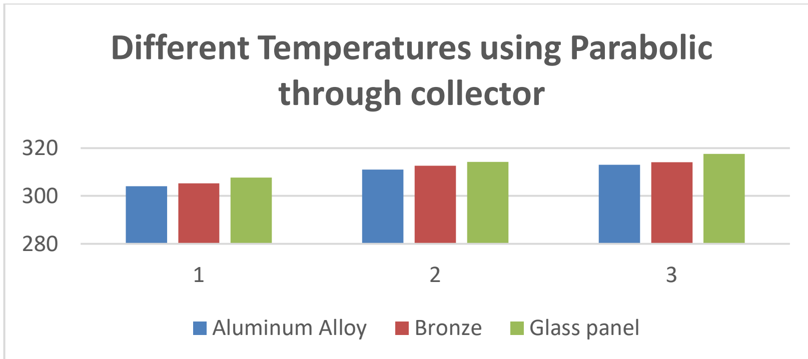

Figure 44: Different Temperatures using Parabolic through collector at various materials

CONCLUSION:

Ansys Workbench is used to model a Parabolic Trough and run simulations at various mass flow rates through the receiver. Parabolic trough collector solar loading is simulated using the Roseland radiation model and solar calculator. The mass flow rate of water through the receiver pipe is varied and all the results obtained were noted. In this study, a simulation of a parabolic trough collector by the commercial software Ansys is presented.

1. The final simulation results are very close to the numerical model. Specifically, the working fluid convection coefficient is calculated and then validated against its theoretical value.
2. It also shows that Ansys provides tremendous features to users by enabling the understanding of all calculated quantities at every place of the model. Aside from being novel, the provided numerical model yields precise results at a reasonable computational price. The convergence of this model is dependent on the relaxation factor. The collector's efficiency is greater than 75% at high temperatures, making this technology advantageous.
3. According to the inlet temperature, the heat loss coefficient varies from 0.6 to 1.3 W/m2 K, explaining the high efficiency.
4. The distribution of solar heat flow over the absorbed surface is the next important variable to investigate because it has an effect on the absorber's temperature profiles. At an angle of 45° from vertical, the absorber sees the most concentration ratio of solar radiation
5. The top portion concentration ratio is close to one, whereas the lower part concentration ratio reaches a maximum of around 27 and a mean of 12.15.
6. The effectiveness of the collector, especially its optical component, is highly dependent on the solar radiation direction.
7. The efficiency of a collector is negatively impacted by a larger incident angle due to increased end losses. High collector performance is achieved for incident angles in the longitude direction of up to 20 degrees, when the angle efficiency modifier is more than 0.8.

8. When the temperature of the sun rises over 70 degrees, the amount of energy captured by the absorber is no longer sufficient to power the collector.

In conclusion, it's important to remember that the optical modifier equation and thermal efficiency equation can be used to evaluate the collector's efficiency in different situations. As a result, this model can be easily incorporated into any suitable simulation software using these equations.

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