International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 06 | June - 2022 Impact Factor: 7.185 ISSN: 2582-3930

DESIGN & CFD ANALYSIS OF SOLAR FLAT PLATE COLLECTOR

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Abstract –
Solar is the loose supply of power to be had in nature . Now, nowadays, most of the devices are electric powered, from vacuum purifiers to electric powered vehicles. 8506 It is usually discovered that power usage inside the residential and commercial packages of water heating structures has now been evolved with the aid of using sun collectors. Even though there are sunwater farmers with unique configurations, they're built with absorber tubes having a round go section. This challenge analyzes the consequences on thermal overall performance while unique shapes and sizes are followed for the tubes (zigzag, u-bent double parallel etc.) of absorber plate.
A constant cross-section along the flow path of various designs and a constant circumference of the flow path of the pipe are included in the analysis as comparative criteria. This study allows us to develop recipes for designing the size and shape of various absorption tube cross sections.

***Key Words*:** optics, photonics, light, lasers, templates, journals

1. INTRODUCTION

• A Flat Plate Collector is a heat exchanger that uses the well-known greenhouse effect to transform the sun's radiant solar radiation into heat energy. As the plate heats up, it is transferred to the fluid running inside the copper pipes, which is then used by the household.
• Solar energy can be captured with a flat plate collector. A conventional flat-plate collector consists of a metal box with a glass or plastic cover on top and a dark-colored absorber plate on the bottom (known as glazing). In order to reduce heat loss, the collector's sides and bottom are normally insulated.
• A flat plate collector (FPC) is made up of fluid tubes that are connected to a darkened (high absorptivity) flat plate absorber
Based on the working medium, there are two categories of collectors.

1.1.1 How many types of flat plate Collector

Flat plate collectors are classified into two categories based on the type of heat transfer fluid used.
• Liquid Heating Collectors and Liquid Heating Collectors
• Heating collectors (air or gas).

1.1.2 Principle of Flat Plate Collector

A flat collector's principle is straightforward. When a metal sheet is exposed to solar radiation, the temperature rises until the rate of energy received equals the rate of heat loss from the plate; this is known as the 'equilibrium' temperature. The equilibrium temperature will be substantially higher than that of the simple exposed sheet if the rear surface of the plate is shielded by a heat insulting substance and the exposed surface of the plate is painted black and covered by one or two glass sheets. Adding a water circulating system, either by making it hollow or by welding metal pipes to the surface, and sending the heated liquid to a tank for storage can turn this plate into a heat collector. Because no useful heat can be extracted at the maximum equilibrium temperature, where the collection efficiency is 0, the equilibrium temperature must decline as heat is removed from the system.
The opposite extreme is when the liquid flow is so flat that the temperature rise is very tiny; in this instance, even though the losses are minimal and the heat collection efficiency approaches 100%, no useable heat can be recovered. The optimum is roughly halfway between the equilibrium temperatures, resulting in a hot liquid output at a practical temperature.

1.1.3 Major Important Parts of Solar Collector

The collector is made up of four basic parts:
1. An absorber plate,
2. Clear covers,
3. An insulated box, and
4. A frame assembly.
The absorber plate, which is usually made of black metal, absorbs the incident solar light and turns it to heat.

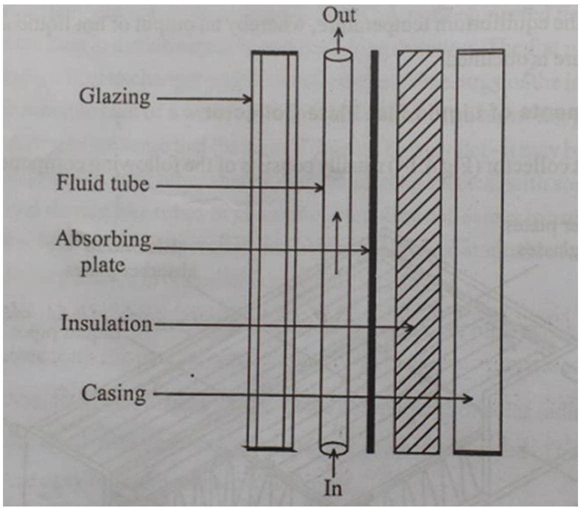
1.1.4 Advantages of Flat Plate Collector

1. They absorb direct, diffuse, and reflected solar energy.
2. They are set in slant and direction, eliminating the need to follow the Sun.
3. They are simple to build.
4. Have a low maintenance cost and a long life cycle, and 5. operate at a high efficiency.

1.1.5 Components of Liquid flat Plate Collector

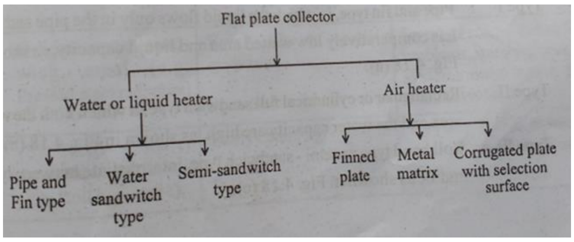
A flat collector (Fig. 4.14) is made up of the following parts:
1. Place a cloth over your spectacles.
2. Plates for absorption
3. Heat trapping back black insulation
4. Casing
5. Tubes or pipes for liquids
6. Fluid circulation inlet and exit Etc.
• Glazing ,which can consist of one or more sheets of glass or other diathermanous (radiation-transmitting) materials.
• Conducting or guiding the heat transfer fluid from the input to the output using tubes, fins, or channels.
• Absorber plate with tubes, fins, or channels connected, which can be flat, corrugated, or grooved.

• Manifolds or headers to admit and discharge fluid.
• Heat loss from the collector's back and sides is minimized thanks to insulation.
• A container or casing that surrounds and protects the individual components from dust and moisture.



1.1.6 Classification of flat collector

Flat-plate collectors are basically divided into two categories according to their use,
(i) Water or liquid heaters and
(ii) Air heaters and
(iii) Air heaters.
These collectors meant for these uses are sub-divided as follows:



2. PROBLEM STATEMENT

It could be a minor problem like a blown fuse or tripped circuit breaker if your electric water heater isn't providing hot water. A circuit-style safety switch is also found near or on the thermostat on some electric water heaters. It could be as simple as running out of gas in the case of gas water heaters. The majority of electric Gizar, coils, and electric water heaters on the market today are used to heat water and require potential energy in the form of electricity to operate. The more energy is used, the more power is generated; most solar items are also accessible, but most people do not purchase them due to the high cost.
As a design engineer, our expertise is to save time, money, and effort in order to solve these issues. As a result, the design considerations for alternative tube paths, cross-sections, and flat plate solar collector parameters will be varied and explored in this project. Material selection has an important role in reducing weight and cost.
1. An excessive amount of warmth
2. Electricity Consumption
3. Rusty water - Corrosion of your tank's inner lining might be caused by a faulty anode rod when heating in a Gizar.
4. It is uneconomical.
5. Raising the temperature too high might cause leaks, loose heating elements, and cracks.

3. OBJECTIVE

1. To make use of available energy that is both free and renewable.
2. To heat the water without the need of a power source or a gas source.
3. To improve the rate of heat transfer by altering the flow channel and comparing it to thermal materials.
4. To investigate the CFD of a flat-plate solar collector.
5. Create a cost-effective system.
6. Lightweight materials should be used for ease of handling.

3.1 Current Study and Project Approach

1. Research online literature publications to determine the project's feasibility.
2. Establish material selection requirements for low weight, thermal application, and improved heat transfer efficiency.
3. To prepare heat conduction in the collector analytically.
4. Create a 3D model with appropriate specifications using CATIA v5 software.
5. In ANSYS workbench, simulate the prepared model in CFD post.
6. To test whether the system can create improved efficiency by varying the flow path by changing the tube variations and solving for FEM.
7. Purchase materials based on the design criteria and material selection.
8. Create the work and put it through its paces to ensure that it is efficient.

4. SCOPE OF THE PROJECT

• Solar energy generation has a huge potential in India. The country's physical location helps it generate solar energy. Because India is a tropical country, it receives solar radiation virtually all year, averaging 3,000 hours of sunshine.
• By 2050, solar PV would be the second-largest power generating source, trailing only wind power, and would pave the path for the global electrical sector's change. By 2050, solar PV will have generated a quarter (25 percent) of the world's total electricity consumption, making it one of the most important generation sources.

Pre-Processing

• Geometry Modeling (using CATIA v5)
• Meshing (using ANSYS)
• Material and Contact Definition (ANSYS library or self-material propagation from online survey)
• Boundary conditions and loading (ANSYS)

Post-Processing & Solution (ANSYS)

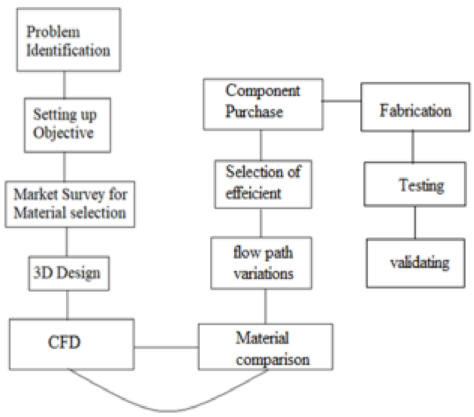
• Transient CFD post-processing
• Pressure
• Velocity stream line

• Temperature distribution inlet, outlet

Facilities Required

To develop the 3D model of the cabin mounting bracket, you'll need the following tools:
• CATIA v5 design tool • Surface designing or wireframe design
• Flow path variation of tube from parallel to u bent
• CFD system
• Material comparison of tubes

5. METHODOLOGY



Step 1: I began working on this topic with a literature review. I've gathered a lot of research articles that are related to this topic. We learned about topology optimization, CFD post & pre-processing, and the alternator project of our goal after reading these publications.
Step 2: - Following the study, the market is surveyed for material selection criteria based on availability and pricing.
Step 3: - Once the materials have been chosen, the 3D model and drafting will be completed using CATIA software.
Step 4: - The FEM solution will be assessed first, followed by a CFD post.
Step 5: Compare the materials.
Step 6: Vary the cross-section of the tube.
Step 7: Invest in materials.
Fabrication is the eighth step.
9th step: testing
Step 10: Validation
Step 11: Compose a thesis

6. LITERATURE REVIEW

1. Solar Flat Plate Collector Design and CFD Analysis Using CREO M.ALEKHYA
The author found the answer with three working mediums using Creao software to simulate the FEA CFD post the heat transfer rate for depending on the working medium.

2. Mr.Arunprasad S, Dr.Saravanan P, and Mr.Arulraj R designed and analysed a flat plate solar air collector.
For the purpose of improving the performance of this project, the author considered working in a medium such as air and various insulation materials.

3. Cfd analysis of triangular absorber tube of a solar flat plate collector
basavanna s and k s shashishekar
To determine the performance, the author modified the tube shape from circular to triangle in this paper.

4. Mohd Irshad, Anshul Yadav, Rajnish Singh, and Anil Kumar Mathematical modelling and performance analysis of single pass flat plate solar collector.
Various effective heat loss coefficients and collector efficiency were found to be 72.7 percent, 8.422 W m-2 K-1, and 36.73 percent, respectively, in this work.

7. LITERATURE GAP

After reading comparable study articles, I noticed that the cross section of the tube was changed from square to circular, semi-circular, and so on, and that many people worked on different fluids with varied parameters. As illustrated below, we can modify the project by using alternative materials for the tube's cross section, changing the course from parallel to zigzag, and adding U-bends.

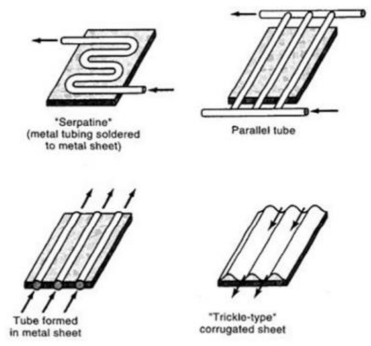


Figure 1 Internal tubing arrangement in flat plate collectors (copyright Saunders College Publishing)

Figure 2 literature gap + current focus on the study

8. PROPOSED SYSTEM FORMULATIONS

Parent section Design parameters

1. Case dimension

a. Shell or thickness = 5mm = 0.005 m
b. Length of the case = 2000 mm = 2m
c. width of the case = 1000 mm = 1m
d. depth of the case = 30 mm = 0.03m
Area=4.329m^2

Assume total weight on collector including tube ,Glazing glass & absorber plate =10Kg

$$\sigma = \frac{Force}{Area} = \frac{10 * 9.81}{4.329} = 22.66\ N.m^2$$

Tube

Tube max diameter = 8mm
Tube min diameter = 6.35 mm
Length of the tube = 1900 mm
Area = πXDminXL=π*6.35*1900=37903.31 mm^2=0.037m^2

Header pipe

a. Pipe max diameter = 14 mm
b. Pipe min diameter = 12.7mm
c. Pipe length = 1050 mm

Collector glass

1. Length of the Thermal glass = 2000mm
2. Width of the thermal glass = 1000mm
3. Depth pf the thermal glass = 3mm

A =2((L*B) +(B*D) +(L*D))
=2((2*1)+(1*0.003) +(2*0.003)) = 4.018m3

Absorber plate

Length of the absorber plate copper = 1950mm
a. Width of the absorber plate copper = 950mm
b. Thickness of the absorber plate copper = 0.16 mm

Water velocity is a measure of the speed of water flowing through a closed pipe system. Water velocity can be determined using a simple formula:
V = Q/A

Where,

- V = velocity
- Q = Flow rate
- A = cross-sectional area of pipe

The cross-sectional area of a pipe can be determined using the formula:
A = πr²
R = radius of pipe mm = 6.35 mm
A=π* 〖6.35〗 ^2 = 126.67 mm2
Q = let us assume that the total water to be discharge is of 25 LPM
10 liter/minute = 0.0001666667 cubic meter/second
Q = 0.0004166667m^3/sec
= 0.41 kg/sec
V=0.0004166667/126.67= 3.2896e-6 m3/sec

Parameter Value

- Solar radiation 1200 W/m2
- Mass flow 0.41 kg/s
- Assume outlet temperature 317.55 k
- Water inflow temperature 295 K
- 5. Velocity of the water = 3.2896e-6 m/sec
- The specific heat capacity of water is 4184 J·kg−1·c−1.
- 7. Collector area = 4.18m2

The solar collector's efficiency is governed by
The following assumptions were used to conduct the analysis:
• The temperature has no effect on the physical and thermal qualities of the absorber plate, pipe, or water.
•Water is a never-ending and incompressible fluid.
•The flow is steady and has laminar properties.
•Heat is lost from the bottom of the plate and tube through convection, which is affected by wind speed.
•The upper portion of the plate receives a steady heat flow (solar radiation), while the lower section is set up as a convective surface, with Gunjo calculating the convective h
Where:
m = Mass flow of fluid, kg/s
Cp = Specific heat of the fluid, J/kg-K
Ti = Fluid inflow temperature, K
To = Fluid outflow temperature, K
I = Solar radiation, W/m2
Ac = Effective area of the collector, m2
Heat gained through radiation

Q/t=σeA(T_2^4-T_1^4)
where σ = 5.67 × 10−8 J/s · m2 ·
K4 is the Stefan-Boltzmann constant,
A is the surface area of the object, and
T is its absolute temperature in kelvin.
The symbol e stands for the emissivity of the object, which is a measure of how well it radiates. An ideal jet-black (or black body) radiator has e = 1,
whereas a perfect reflector has e = 0. Real objects fall between these two values. Take, for example, tungsten light bulb filaments which have an e of about 0.5, and carbon black (a material used in printer toner), which has the (greatest known) emissivity of about 0.99.

Heat transfer in a parallel tube
Area of parallel tube = 0.037m^2 calculated are
Figure area of parallel tube from CATIA
Where
Q = heat transfer through radiation
A = Area tube
T1 & T2= temperature difference eat transfer coefficient.

Heat transfer in u bent tube

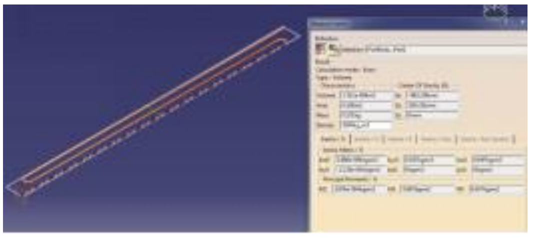


Figure 3 u bent cross-section

Q=1*5.67e-8*0.108(〖317.55〗^4-295^4)=15.890W
Hence the heat transfer rate compared to parallel and U – bent case, U- bent tube as much better heat transfer rate in winter season.

9. DESIGN

Procedure for 3D Development of model.

•Download a trace 2D sketch of any car model that has standard measurements available.
•Open CATIA software, go to Shape Designing, pick Sketch Tracer, select the downloaded 2D drawing, and extract all the views on the needed plane, then build an immersive sketch.
•Now that the importing is complete, trace the sketch using the free style section on the chosen plane. (Creating a spline on a 2D drawing is referred to as tracing.)
•Use curvature to create nodes and join them together.
•Remove the area to the surface,
•Insert more material
•Adjust the thickness of the thick surface to the appropriate value.
•For ANSYS import, convert to an IGS or STP file.

Parent section:

Absorber plate

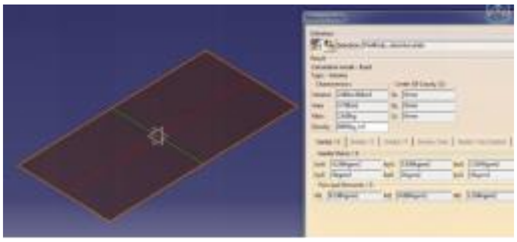


Figure 4 absorber plate

Assembly

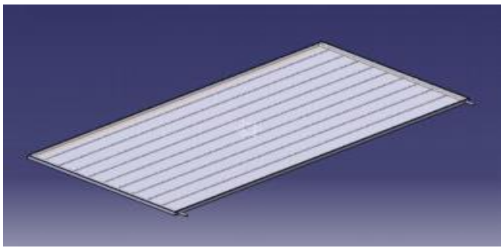


Figure 5 assembly of all sub parts

1. Tubes
2. Absorber plate
3. Glass
4. Collector
5. Black paint

Proposed design

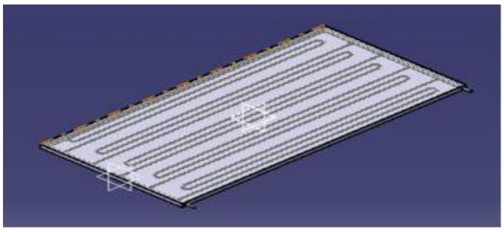


Figure 6ISO view of proposed system u tube bent

Parameters

• Pitch between two parallel tubes is 50 mm, curve module is 50 mm, u bent tube length is 1800 mm on one side, and overall tube length from fixed to foxed is 1900 mm.

• We'll convert this file into IGS or STP and utilise it to solve the FEM solution because we're using 5 tubes with the same diameters as the parent section.

Until now, analytical calculations have been completed and design parameters have been established, as well as research on the flat collector's operation, terminology, materials, and so on. We'd provided a list of items that could be employed to improve the collector's performance.

10. CONCLUSIONS

Until now, analytical calculations have been completed and design parameters have been established, as well as research on the flat collector's operation, terminology, materials, and so on. We'd provided a list of items that could be employed to improve the collector's performance.

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