Thermal Analysis of Solar Flat Plate Collector Using CFD

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***Abstract*- The main objective of this paper is to present design of solar flat plate collector using CAD software to perform thermal analysis in the month of March at 11am, 12, 1pm & 2pm and keeping the mass flow rate as constant. For modeling purpose GAMBIT 2.4 is used & for analysis ANSYS FLUENT 14.5 is used.**

Keywords— Modeling, Thermal Analysis.

I. INTRODUCTION

Solar based energy is radiant light and warmth from the Sun that is saddled utilizing a scope of always developing advancements, for example, sun oriented warming, photovoltaic, sun based warm vitality, sun based engineering, liquid salt power plants and fake photosynthesis.[1][2]

It is a critical wellspring of sustainable (renewable) power source and its advancements are extensively portrayed as either detached sun oriented or dynamic sun based relying upon how they catch and disperse sun based vitality or change over it into sun based power. Dynamic sun based strategies incorporate the utilization of photovoltaic frameworks, concentrated sunlight based power and sun based water warming to outfit the vitality. Uninvolved sun based methods incorporate arranging a working to the Sun, choosing materials with good warm mass or light-scattering properties, and outlining spaces that actually flow air. In order to affect the performance of this system, generally indeed studies on solar collectors is required [3]

II. CONSTRUCTION AND WORKING OF FLAT PLATE COLLLECTOR

A. Flat Plate Collector

Flat plate collectors are most common for residential water- heating and space-heating installations. A flat plate collector consists of an absorber, glazing covers and an insulated box as shown in fig 1. The absorber is sheet of high thermal conductivity metal sheet with tubes integral attached. The insulated box provides structure and sealing and reduces heat loss from the back and sides of the collector [4]. The cover sheets, called coating, permit daylight to go through to the safeguard however protect the space above to keep cool air from streaming into this space. The glass mirrors a little piece of the daylight, which does not achieve the safeguard. The safeguard plate which covers the full opening range of the gatherer performs three capacities: assimilate the most extreme conceivable measure of sun oriented irradiance, move this warmth into working liquid at the very least temperature contrast and lose a base measure of warmth back to the environment. Sunlight based irradiance going through the coating is consumed specifically onto the safeguard plate. As the second capacity of the safeguard plate is to exchange the consumed vitality into a warmth exchange liquid at any rate temperature distinction, is accomplished by directing the retained warmth to tubes that contains the warmth exchange liquid.

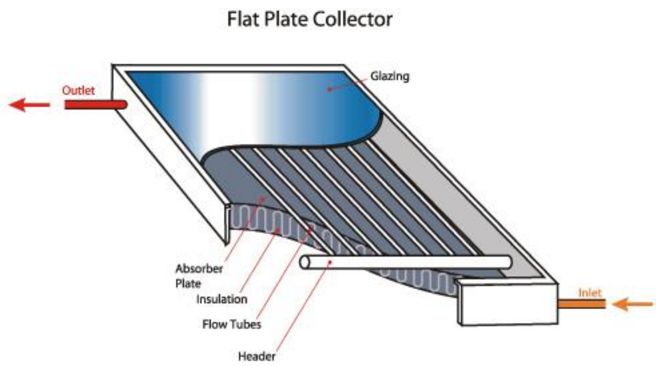

Fig.1. Solar Water Flat Pate Collector

Transferring the heat absorbed on the absorber surface into the water give rise to heat losses. Liquid collector absorber plates consist of a flat sheet with tubes spaced 10cm apart and attached to it. The tubes are not spaced too apart otherwise a much lower temperature will occur halfway between them.

III. HEAT TRANSFER

A. Principle of Heat Transfer

Heat Transfer is the thermal energy exchange between bodies when there is a temperature differences them. Thermal energy is transferred from the higher temperature, to the lower temperature. Temperature is a measure of the measure of vitality (energy) atoms a body holds. In SI units, heat is typically denoted by the symbol Q and it is expressed in joules (J). The rate of heat transfer q is measured in watts (W), which are joules per second. The rate of heat transfer per unit area, heat flux, is measured in watts per area (W/m^2).

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B. Modes of Heat Transfer

Heat transfer processes are classifies into three modes: conduction, convection & radiation. Conduction occurs when there is a temperature gradient across a body. It is an energy transfer across a system due to random molecular movement. Higher temperature is related with higher molecular energies, hence when they collide with molecules of lower energy and conduction occurs.

The second heat transfer process is convection where the motion of fluids (gas or liquids) is used to transfer heat. The convection heat transfer can be natural (free) convection where the fluid motion is created by the warm fluid itself. The density of fluid decreases as it is heated and it becomes lighter than the cold fluid. Forced convection occurs when the flow is caused by external means, such as pumps.

The third process is radiation where the transmission of energy is achieved without the presence of a body. Radiation travels at the speed of light and it is emitted by any matter with temperature above 0 K. This mode of heat transfer takes place when the emitted radiation strikes another body and it is absorbed [5].

IV. DESIGNING

A. Concept Selection

In recent years solar energy has been strongly promoted as a viable energy source. One of the simplest and most direct applications of this energy is the conversion of solar radiation into heat. Hence way that domestic sector can lessen its impact on the environment is by installation of solar flat plate collectors for heating water. Although it should be said that some of these collectors have been in service for last 40-50 years without any real significant core studies in their design and operational principles.

So, research work done and presented in this paper is concerned with detailed study of solar flat plate collector to increase the heat transfer. This is examined by the design of collector model utilizing computational Fluid Dynamics (CFD) ANSYS Fluent package.

B. Design Consideration

The proposed CFD design employs a geometry consisting of two vertical cylindrical pipes and 19 horizontal pipes. The software works involves simulation conducted on the design equipped with two glazed solar collector.

The basic parts of the full-aperture are absorber plate, two transparent covers sheets and insulation. Including to these parts, air gap between the top glass cover and bottom glass cover and air gap between bottom glass cover and absorber plate are also considered as volumes. Specifications of all parts of Collector are shown in table 1.

TABLE 1 SPECIFICATION

Description	Specification	Material
Area of Glazing Cover	10193.5 sq.cm	Glass
Area of Absorber Plate	10193.5 sq.cm	Copper
Diameter of Tube	1.6 cm	Copper
Insulation Thickness	4 cm	Wool

The absorber sheet is of high thermal conductivity metal with tubes attached. To minimize radiant emission, the cover sheet called glazing is used. Outer faces of the water volumes are considered as pipes while doing the simulation using shell condition process[6].

C. Modelling

The full geometry of collector were created in the Gambit Software using the various features available in gambit to create various parts of collector with the help of specifications given in table 1 to get the model of the collector which is shown in fig 2, Computational mesh is used as a pre-processor for the CFD solver and post – processor, namely FLUENT in gambit.

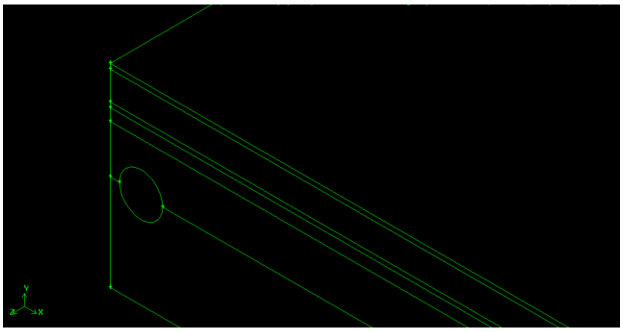

Fig.2. Assembly View of Flat Plate Collector

A time consuming process while designing the proposed geometry was the creation and later meshing of the volume of the water within the pipe. The difficulty occurred because of the complex shape of this particular volume of water. This was due to the large number of pipes created at the external surface of the water because of parallel connection as shown is shown in fig 3. That shape is then projected at the volume water. The computer package had difficulties in dealing with this profile.

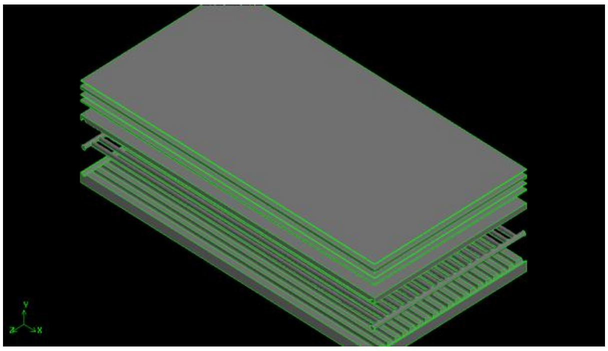

Fig.3. Exploded View of Collector

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D. Meshing

The meshing element-scheme used for meshing the whole domain was Tetrahedral/Hybrid. This scheme allowed the mesh to be composed primarily of tetrahedral mesh elements including wedge (prism) elements where appropriate. The total number of mesh cells created in the entire geometry was about 72.60 lacks with density of the grid being grater in some areas as shown in fig 4.

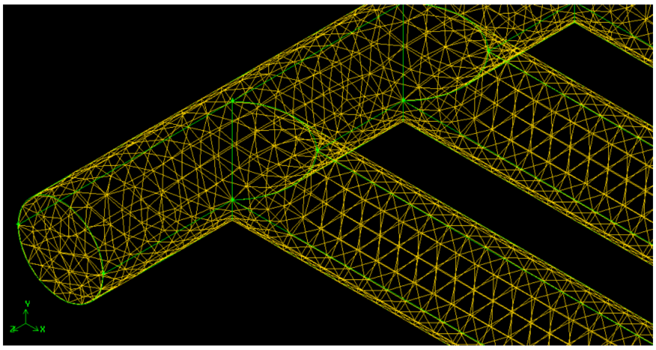

Fig.4. Meshed Pipe

In the pre-processor program i.e., GAMBIT volumes are specified for meshing operation, shape and topological characteristics and type of mesh are also determined. Meshing Scheme is specified by two parameters i.e., elements and type. The elements parameters define the shape of the elements that are used to mesh the volume while type parameter defines the meshing pattern of mesh elements in the volume.

E. Location of Simulation

The location for performing simulation is chosen as Lords Institute of Engineering & Technology, Mechanical Branch as shown in fig 5. The Coordinate for the location is 17.3422° N, 78.3675° E. The location is suitable to run the simulation because the area receives sufficient amount of sun radiation.

Fig.5. Satellite Image of the Location [7]

V. ANALYSIS

A. Analysis of Collector

After giving all the necessary inputs i.e. properties of various volumes of collector to the software as shown in table 2 it performed the calculations inside it and gives the related output in the form of counters for distribution of parameters, reports which includes data at various faces and graphs.

TABLE 2 PROPERTIES

Description	Density (Kg/m^3)	Cp (J/kgK)	Thermal Conductivity (W/m-k)
Glass	2400	670	0.96
Copper	8978	381	387.6
Insulation Wool	48	670	0.05
Air	1.225	1006.43	0.0242
Water	998.2	4182	0.6

After performing simulation on the four cases i.e., at 11am, 12, 1pm & 2pm, weather conditions at 12.00 shows good results. Temperature in glazing covers, air gaps, absorber plate, insulation and outlet of flat plate collector is more at 12.00. Solution of the solar flat plate collector is converged at 815 iterations.

Overall temperature distribution in complete Collector at 12.00 in the month of March is shown in fig 6.

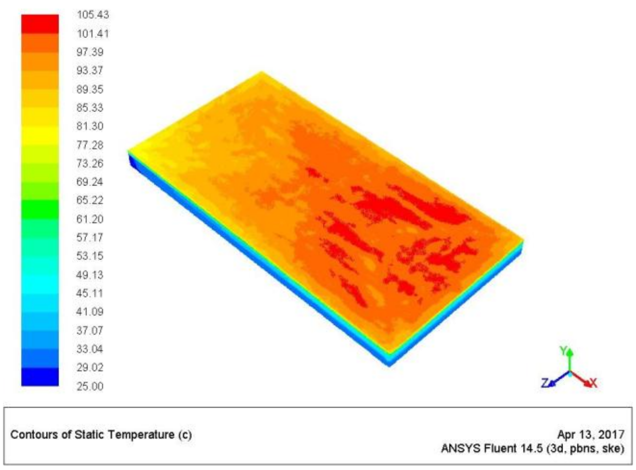

Fig.6. Temperature distribution in collector at 12.00

Temperature distribution in pipe is progressively increases from inlet of the pipe to outlet in cross manner as shown in fig 7.

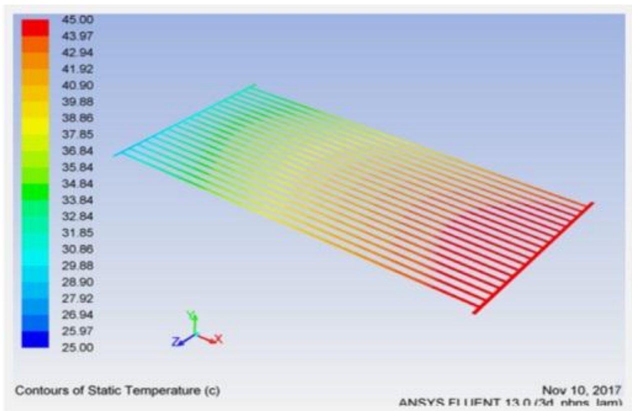

Fig.7. Temperature Distribution in Pipe at 12.00

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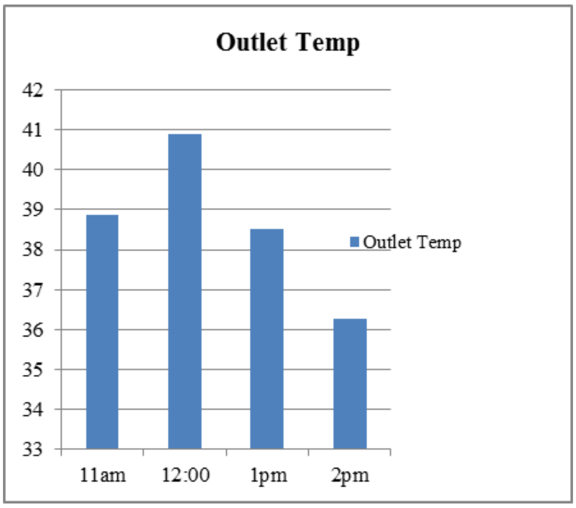
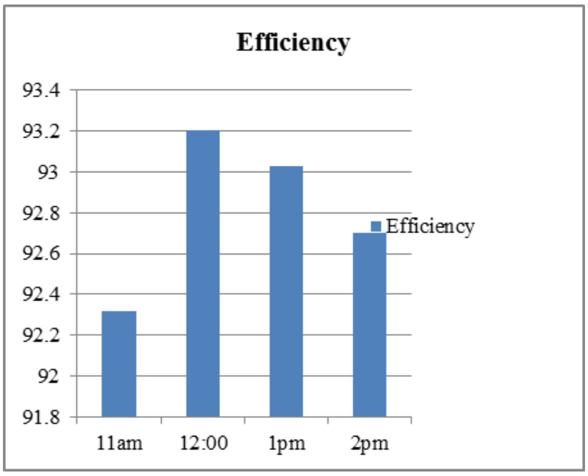
VI. CONCLUSIONS

From the simulation of FPC at 11.00am to 2pm with respect to time is calculated. The output temperature is more in 12:00 collector i.e., 40.89^{o}C when the inlet temperature of water is 25^{o}C so there is an increase in 15.89^{0}C and as the time increases output temperature is decreases as shown in graph 1



Graph.1. Outlet Temperature Variations

Similarly the efficiency is also more in case of 12:00 collector i.e., 93.2% and gradually decreases as time increases as shown in graph 2.



Graph.2. Efficiency Variations

From these graphs output temperature and Efficiency were maximum in Solar Flat plate collector at 12:00.

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[7] Satellite Image of Location ,www.google.com/map

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