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# Performance Analysis of Solar Flat Plate Collector of Different Absorbing Materials using Computational Fluid Dynamics

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**ABSTRACT:** Performance analysis of solar flat plate collectors with different absorbing tube materials is an important topic in renewable energy research. In this study, computational fluid dynamics (CFD) simulations were used to analyze the performance of solar flat plate collectors with various absorbing tube materials. Computational Fluid Dynamics (CFD) has emerged as a transformative tool in aerospace engineering, enabling engineers to simulate and analyze complex fluid flow phenomena critical for the development of next-generation aircraft and spacecraft. This abstract analyze how efficiently the water is heated if the copper pipes are replaced with the aluminium pipes or some different materials in the Solar Flat Plate Collector. By using CFD mass flow rate, pressure variations, water outlet temperature is observed. The study will use ANSYS Fluent simulations to analyze the performance of solar flat plate collectors with different absorbing tube materials. Performance analysis have been conducted by using copper and aluminium as absorbing plate and tubes at 10AM, 12PM, 2PM and 4PM. The result shows that copper and aluminium bestow performance.

**KEY WORDS:** Solar Flat Plate Collector, Absorbing tube materials, ANSYS Fluent, CFD.

## I. INTRODUCTION

A Flat Plate Collector is a heat exchanger that converts the radiant solar energy from the sun into heat energy using the well known greenhouse effect. The flat-plate systems normally operate and reach the maximum efficiency within the temperature range from 30 to 80 oC however, some new types of collectors that employ vacuum insulation can achieve higher temperatures (up to 100 oC). Due to the introduction of selective coatings, the stagnant fluid temperature in flat-plate collectors has been shown to reach 200 oC.

CFD analysis on solar flat plate collectors involves the use of computational fluid dynamics (CFD) to simulate and analyze the flow of air or fluid through the collector. This type of analysis can help to optimize the design of the collector and improve its efficiency by identifying areas of high heat loss or poor heat transfer.

### A Very Brief History Of CFD

The basis of CFD is rooted in the Navier-Stokes equations, which were finalized by Sir George Stokes when he added the viscous terms in the mid-19th century. Using these equations, along with computers, Los Alamos National Lab developed many modeling techniques for fluid flow in the 1950s and 1960s. The first scientific paper that uses a 3D model in fluid flow problems was published by John Hess and A.M.O. Smith in 1967. Further algorithm development was carried out by Brian Spalding and Suhas V. Patankar at Imperial College London during the 1960s and 1970s, most notably the SIMPLE Algorithm. The first commercial CFD software, PHOENICS, was released in 1981. Today, with much more powerful computers, CFD has become an integral part of the design process for a variety of industries.

### Why use CFD?

CFD analyses have a great potential to save time in the design process and are therefore cheaper and faster compared to conventional testing for data acquisition. Furthermore, in real life tests a limited amount of quantities is measured at a time, while in a CFD analysis all desired quantities can be measured at once, and with a high resolution in space and time. Because CFD analyses approximate a real physical solution, it should be noted that these CFD analyses cannot fully exclude physical testing procedures. For verification purposes tests should still be performed.

### How does CFD work?

A CFD analysis basically consists of the following three phases:

#### Pre-processing

In this phase the problem statement is transformed into an idealized and discretized computer model. Assumptions are made concerning the type of flow to be modelled (viscous/inviscid, compressible/incompressible, steady/non steady). Other processes involved are mesh generation and application of initial- and boundary conditions.

#### Solving

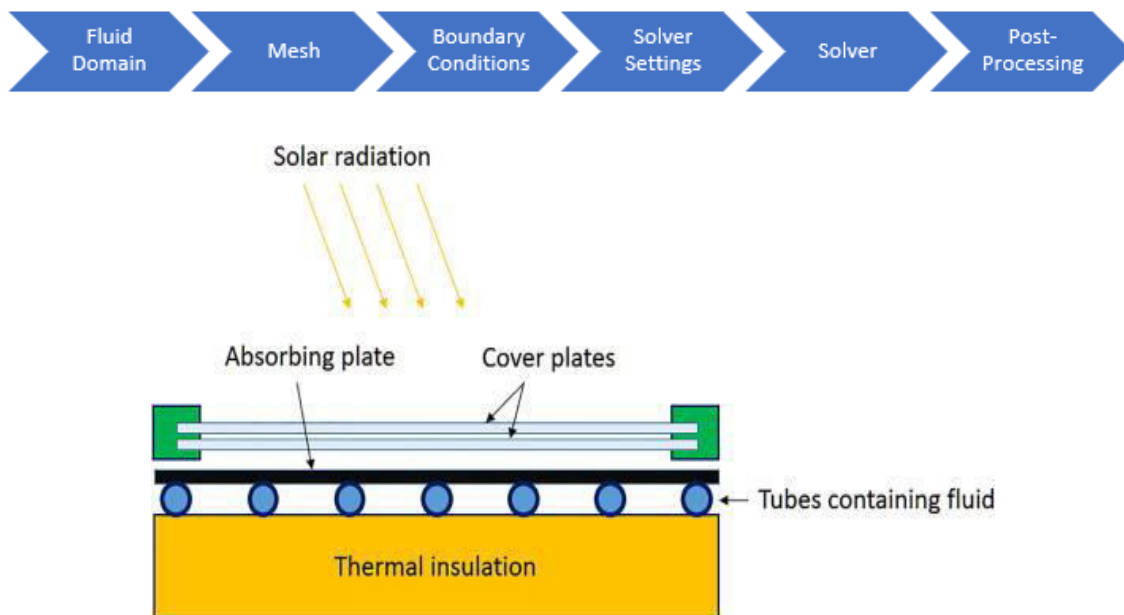
The actual computations are performed by the solver, and in this solving phase computational power is required. There are multiple solvers available, varying inefficiency and capability of solving certain physical phenomena.

#### Post-processing

Finally, the obtained results are visualized and analysed in the post processing phase. At this stage the analyst can verify the results and conclusions can be drawn based on the obtained results. Ways of presenting the obtained results are for example static or moving pictures, graphs or tables.

### The CFD Process

In order to apply the FVM, CFD requires a fluid domain that is discretized into smaller shapes called cells. Once the domain is modelled and discretized, boundary conditions and solver settings must be defined to allow the solver to solve the problem. Many different outputs are available, including pressure, velocity, temperature, forces, etc. Many different types of output plots are also available, including streamlines, isosurfaces, and surface plots. This is where CFD gets the reputation for generating very beautiful and colorful maps



1. **Design and Modeling of the Solar Flat Plate Collector using SolidWorks Software:** This step involves utilizing SolidWorks, a computer-aided design (CAD) software, to create a detailed 3D model of the solar flat plate collector. The design process includes specifying dimensions, shapes, materials, and other relevant parameters to accurately represent the physical structure of the collector.

2. **Importing the Model into ANSYS Fluent Software for CFD Analysis:** After completing the design in SolidWorks, the next step is to import the model into ANSYS Fluent, which is computational fluid dynamics (CFD) software. This software allows for the simulation of fluid flow, heat transfer, and other related phenomena within the solar collector.



3. **Creating the Mesh for the Model using ANSYS Meshing Tool:** Meshing is the process of dividing the geometry of the model into discrete elements or cells to facilitate numerical analysis. In this step, ANSYS Meshing tool is used to generate a mesh that accurately represents the geometry of the solar collector. The mesh quality plays a crucial role in the accuracy and efficiency of the simulation

4. **Defining the Boundary Conditions and Material Properties for the Simulation:** Boundary conditions and material properties are essential inputs for any simulation. In this step, the boundary conditions, such as inlet/outlet conditions, temperature profiles, and solar irradiance, are defined based on the operational environment of the solar collector. Additionally, material properties, including thermal conductivity, density, and specific heat, are specified for the materials used in the collector.

5. **Running the Simulation and Analyzing the Results:** Once all the necessary inputs are defined, the simulation is executed using ANSYS Fluent. The software solves the governing equations of fluid flow and heat transfer numerically to predict the performance of the solar flat plate collector under specified conditions. After the simulation is complete, the results are analyzed to evaluate parameters such as temperature distribution, heat transfer efficiency, and fluid flow patterns. This analysis helps in optimizing the design and operational parameters of the solar collector for enhanced performance.

## II. RESULTS AND DISCUSSIONS

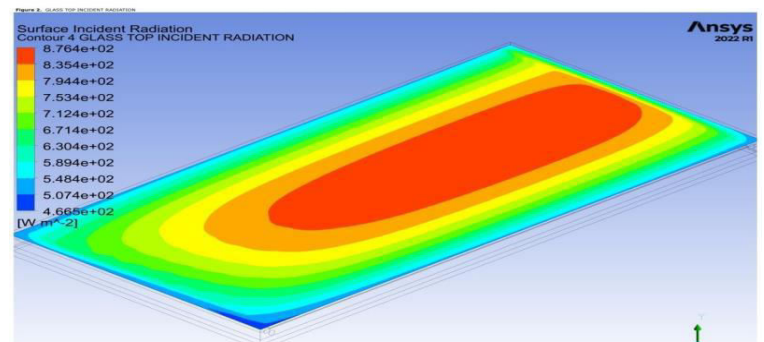
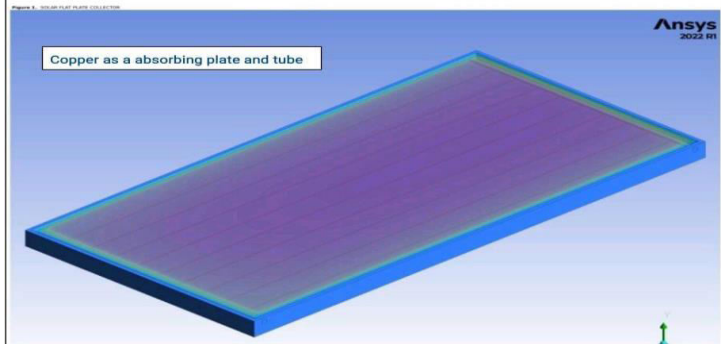
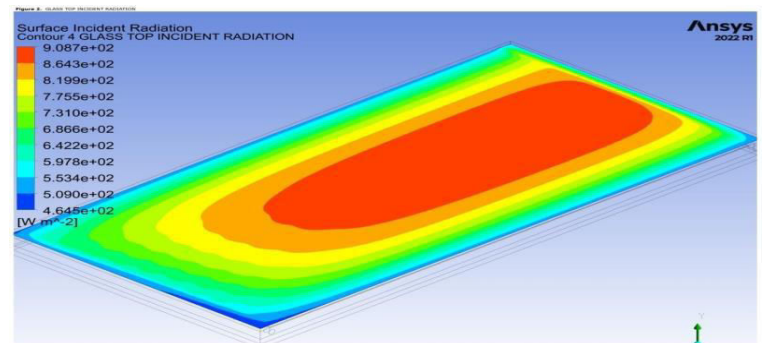
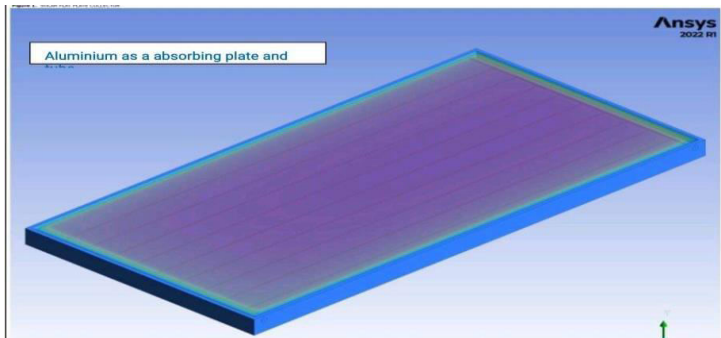
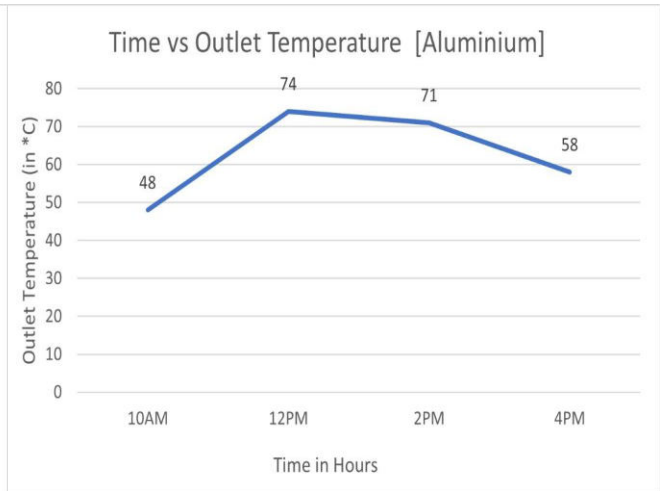
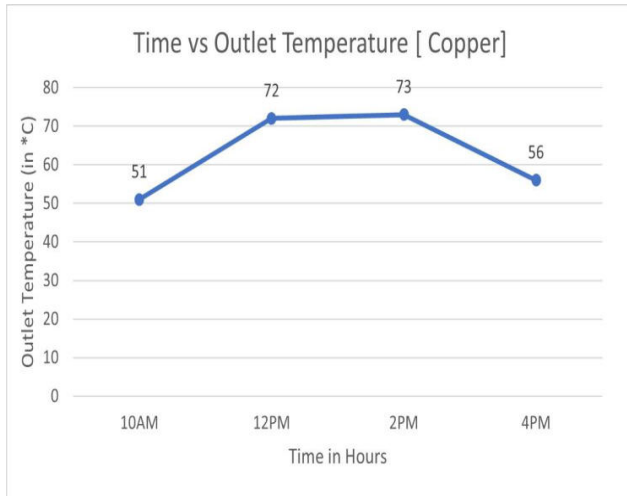
- 1. Water temperature at the inlet 26.85 oC
- 2. Mass flow rate of water at the inlet 0.001 m/s

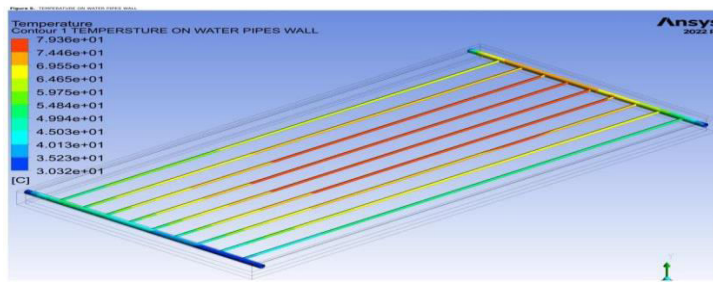
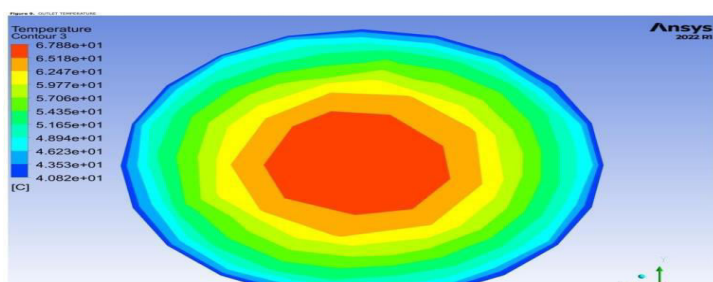
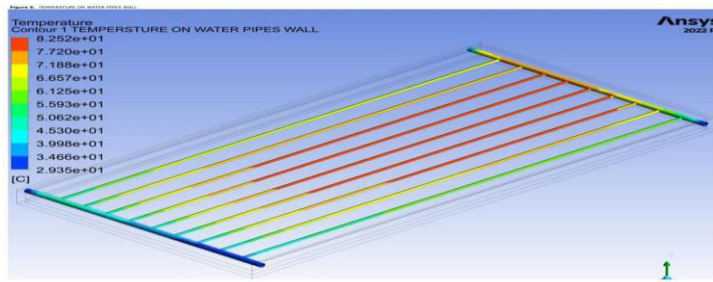
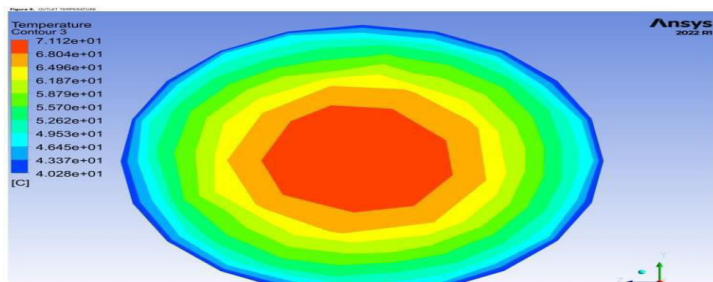
Tabular column- Solar flat plate collector outlet temperatures for different time

Copper- Absorbing tube and plate				Aluminium coated with copper oxide – Absorbing tube and plate			
Sl no.	Time	Intensity of Solar radiation incident on collector (W/m <sup>2</sup> )	Outlet water temperature (in °C)	Sl no.	Time	Intensity of Solar radiation incident on collector (W/m <sup>2</sup> )	Outlet water temperature (in °C)
1.	10AM	658	51	1.	10AM	659	48
2.	12PM	921	72	2.	12PM	955	74
3.	2PM	940	73	3.	2PM	909	71
4.	4PM	737	56	4.	4PM	765	58

### Mesh Report

Domain	Nodes	Elements
absorber	1242499	338218
air box	7368825	1387483
air glass	641194	131136
frame	643853	125734
insulator	285999	56015
water fluid	2155740	417999
All Domains	12338110	2456585





### III. CONCLUSIONS

Experiments conducted on flat plate collectors have yielded several significant conclusions regarding their efficiency and performance under various conditions. Firstly, it was observed that collector efficiency is influenced by factors such as tilt angle, flow rate, and wind velocity. Under specific conditions, the efficiency of the collector increases until it reaches a maximum value, beyond which it decreases. This relationship suggests the importance of optimizing these parameters for maximum efficiency. Secondly, an inverse correlation between collector efficiency and wind velocity was noted. As wind speed increases, it diminishes the impact of solar intensity and cools the collector, thereby reducing its efficiency. Thirdly, the efficiency of flat plate collectors is maximized when there is a maximum fluid temperature difference. This highlights the significance of thermal differentials in enhancing collector performance. Moreover, it was observed that while increasing mass flow rate initially improves efficiency due to enhanced heat transfer, there comes a point where further increases lead to diminishing returns as heat transfer to the flowing fluid decreases. Furthermore, variations in external conditions during tests, such as solar irradiation intensity and inlet temperature, underscore the dynamic behavior of solar collectors. Understanding this dynamic behavior is crucial for optimizing flat plate collector designs. Lastly, critical parameters affecting collector performance include the thickness and coating of the glass cover, material and thickness of the absorber plate, air gap between the absorber plate and glass cover, distance between risers, and insulation materials. Optimizing these parameters can significantly enhance the efficiency and effectiveness of flat plate collectors in harnessing solar energy.

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