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Enhancement of Thermal Performance of Absorber Flat Plate Solar Collector

Amrit Ranjan, Parag Mishra, Ajay Singh

Abstract**:** ***The main objective of this work is to improve the heat transfer rate by changing the design of the absorber flat plate and to compare the different results of computer-assisted fluid dynamics analysis for all designs. In this work, fluid dynamics analyzes were performed for six flat plate vacuum absorbent designs to improve temperature distribution and heat generation to improve thermal performance, variable as axial and radial speed, pressure distribution, function of flow, etc. The interpretation 4 is 15.339% more efficient than the basic design in terms of maximum temperature and thermal power, which was increased by 8.14% compared to the basic design. It is recommended that version 4 of the flat absorbent plate is optimal for better heating.***

Keywords **:** ***Heat transfer, Solar plate, Computational fluid dynamics***

I. INTRODUCTION

The evacuated flat-plate sensor concept was proposed more than 40 years ago, but despite its known advantages, very few manufacturers have developed commercial versions. This article demonstrates the reduction of the heat loss coefficient and the increase in efficiency resulting from the evacuation of a plate collector. It is hoped that these results will be of interest to the concept. Vacuum tubes are now mass-produced in large quantities. Vacuum plate manifolds could fundamentally replace these tubes if the technical difficulties associated with the manufacture of foam glass joints can be overcome.

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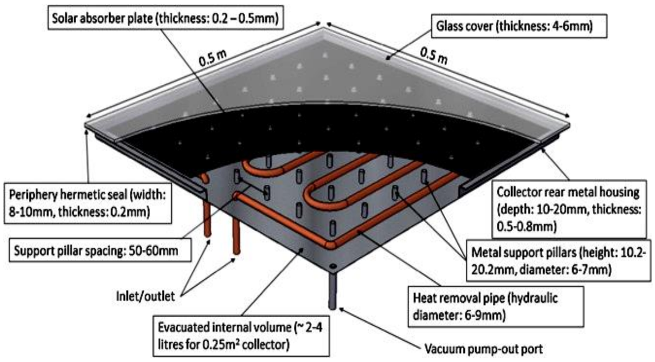

Figure 1: Conceptual depiction of vacuum flat plate solar thermal collector

The evacuated flat plate collectors must combine the high filling factor, the ease of cleaning and the visual aesthetics of the flat collectors with the low coefficient of heat loss of the vacuum tubes. A network of ribs or columns is required to support the protective glass against atmospheric pressures. These sensors can work effectively in low light conditions and also reach "average" or "high" outlet temperatures for industrial applications, a field that has recently attracted interest. The global potential for the industrial use of solar heat is estimated at 180 GW.

It is known that flat collectors, unlike some evacuated collectors, do not require maintenance and generate little or no cost during their life. The vacuum collectors are the most suitable for solar treatment applications. From an economic point of view, this type of sensor for solar hot water or space heating is of little interest because it still offers the largest market share of solar collectors.

Figure 2: Tray type absorber plate of stainless steel with the pin

Solar thermal collectors

There has already been a lot of work to heat the pool water with solar collectors. Solar collectors can generally be divided into two broad categories: concentrated and non-concentrated. Concentration sensors generally use parabolic mirrors / concave / reflectors to focus all the solar energy incident on the sensor surface.

The surface of the sensor is therefore generally very wide and the temperature reached is very high. For applications such as pool heating, non-concentration sensors are generally preferred. Flat plate collectors and vacuum tube collectors are the two most commonly used types of non-concentrated collectors. Flat plate collectors are the primitive types of manifolds that are easy to produce and require only very low maintenance costs. Vacuum tube sensor technology is still relatively new and is suitable for areas with low sunlight or low ambient temperatures. Flat-plate collectors rely on a large surface and warm pool water in places like India, where there is plenty of sunshine all year round.

Studies have shown that, despite the high heat losses in flat-plate collectors, good designs based on heat transfer technology can give better results than vacuum tube collectors.

The vacuum collectors can absorb the diffused light and work without locating the sun. The flat covers of the EFP sensors are more attractive than the vacuum tube bundles and combine with the high efficiency for roof integration. The vacuum provides effective insulation between the front and rear covers, helping to minimize heat loss from the absorber. The vacuum sensors can therefore replace the traditional insulated or vacuum insulated panels and are more efficient at higher temperatures than other types of solar collectors up to 210 ° C.

A solar thermal system has many applications such as water heating, appliances, irrigation, fruit and vegetable drying, wood, coconut, etc. A solar thermal system can heat water or air. Normally, solar panels are installed on the roof or a frame on the ground floor and a hot water tank is installed near the sensors.

II. OBJECTIVES

There are following objective are to be expected from the present work

1. The main objective of the present work to enhance heat transfer rate by changing design of absorber flat plate.
2. To perform theoretical investigation about absorber tube of flat plate collector.
3. To perform computational fluid dynamics analysis on design from base paper as well as different proposed design of absorber plate of flat plate collector.
4. To compare the various results obtained from computational fluid dynamics analysis on all designs.

III. METHODOLOGY

Six different design of CAD model of absorber plate of evacuated flat plate collector is created with the help of design modular of ANSYS workbench. For the meshing triangular & rectangular shape elements have been generated with very fine mesh. The quality of the cell including its orthogonal quality, aspect ratio, and skewness has an important effect on the accuracy of the solution. Orthogonal quality is computed for cells using the vector from the cell centroid to each of its faces, corresponding face area vector, and the vector from the cell centroid to centroids of each of the adjacent cells.The working fluid is taken as water flowing inside the absorber tube of parabolic trough collector having density of 1000 kg/m^3, specific heat = 4182 J/kg-k, thermal conductivity = 0.6 w/m-k and viscosity of water liquid = 0.001003 kg/m-s. For the boundary conditions set fluent launcher options as double precision for 64 bit processor, for thermal aspect enable energy equation on, Pressure based absolute velocity formulation steady state fluent solver is used for this analysis.

Heat transfer by absorber flat plate :-

$Q = mc_p\text{-}\Delta t \quad W$

Computational fluid dynamics analysis for absorber plate of evacuated flat plate collector:

In the present work a three dimensional CAD model of absorber plate of evacuated flat plate of design-1 having hole size 10 mm diameter in regular pattern with array spacing 5 mm is created with the help of design modular of ANSYS workbench as shown in figure No.

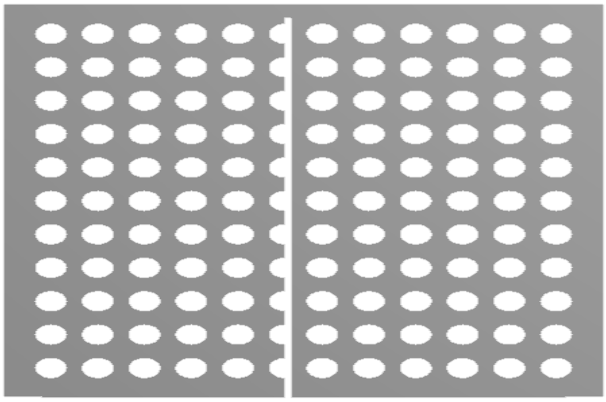

Figure 3: CAD model of absorber plate of evacuated flat plate collector

Meshing: Meshing: for the design-1 the total nodes are 476609 and total No. of elements are 467066 which are triangular & rectangular in shape.

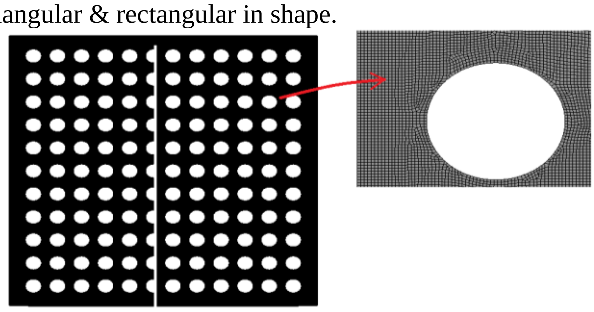

Figure 4: meshing of absorber plate of evacuated flat plate collector

Material properties:

The working fluid is taken as water flowing inside the absorber tube of parabolic trough collector having density of 1000 kg/m^3, specific heat = 4182 J/kg-k, thermal conductivity = 0.6 w/m-k and viscosity of water liquid = 0.001003 kg/m-s.

Boundary conditions of absorber plate of evacuated flat plate collector

1. To determine the maximum temperature inside the absorber plate of evacuated flat plate collector according to base paper need to on energy equation.
2. Viscose laminar flow model is used for fluid flow having velocity inlet of 0.025m/sec.

3. Defining of material property, set fluid as water liquid having density of 1000 kg/m^3, specific heat = 4182 J/kg-k, thermal conductivity = 0.6 w/m-k and viscosity of water liquid = 0.001003 kg/m-s.
4. For the outlet boundary condition the gauge pressure needs to be set as zero because the flow of water inside the absorber plate of evacuated flat plate collector according to base paper is atmospheric.
5. Water inlet velocity of 0.25 m/sec (R. moss 2018) at 23 ºC temperature
6. Pressure based absolute velocity formulation steady state fluent solver is used for this analysis.

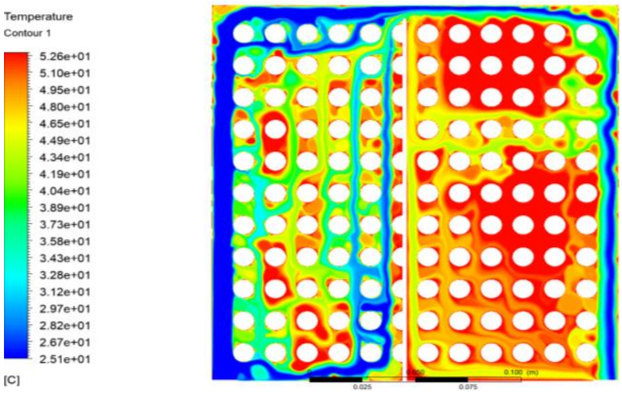

Figure 5: Temperature distribution over the absorber plate of evacuated flat plate collector

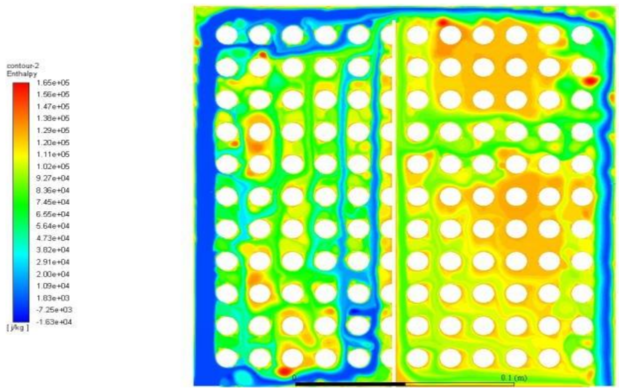

Figure 6: Enthalpy of the absorber plate of evacuated flat plate collector

CFD Analysis for Design-2

CAD model of absorber plate of evacuated flat plate of design-2 having hole size 10 mm in zig-zag pattern with array spacing 5 mm. as shown in figure No. 7

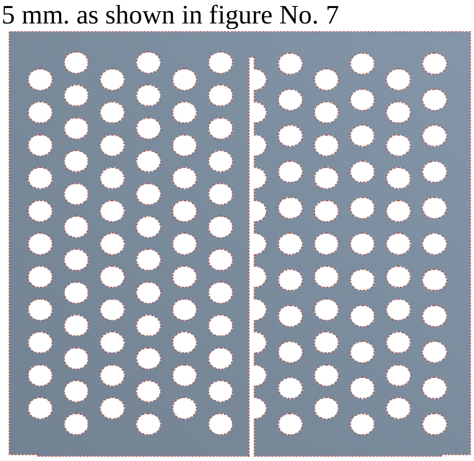

Figure 7:

for proposed design-2

CFD Analysis for Design-3

CAD model of absorber plate of evacuated flat plate of design-3 having hole size 5 mm in regular pattern with array spacing 5 mm as shown in figure No.11

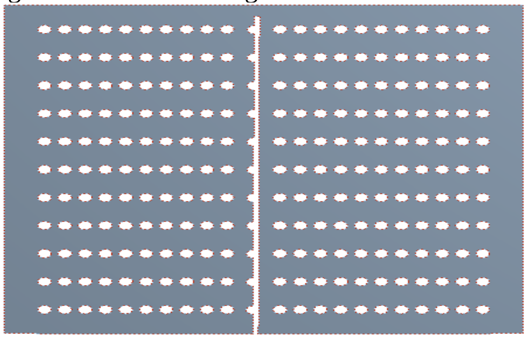

Figure 8: CAD model of absorber plate of evacuated flat plate collector design-3

Meshing: for the design-3 the total nodes are 543181 and total No. of elements are 534510 which are triangular & rectangular in shape.

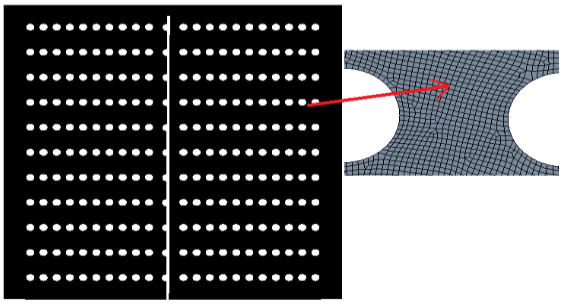

Figure 9: meshing of absorber plate of evacuated flat plate collector design-3

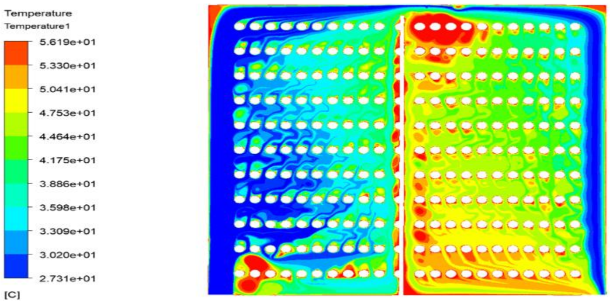

Figure 10: Temperature distribution over the absorber plate of evacuated flat plate collector for proposed design-3

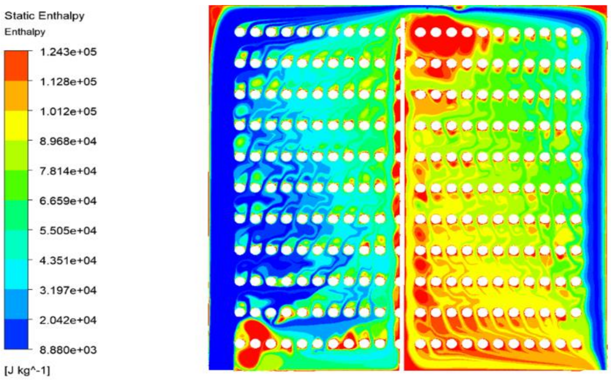

Figure 11: Enthalpy of the absorber plate of evacuated flat plate collector for proposed design-3

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CFD Analysis for Design-4

CAD model of absorber plate of evacuated flat plate of design-4 having hole size 5 mm in zig-zag pattern with array spacing 5 mm as shown in figure No. 15

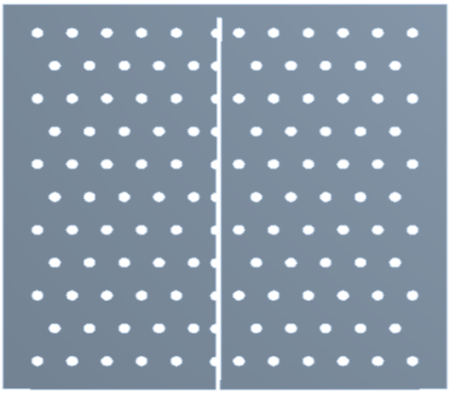

Figure 12: CAD model of absorber plate of evacuated flat plate collector design-4

Meshing: for the design-4 the total nodes are 568372 and total No. of elements are 563002 which are triangular & rectangular in shape.

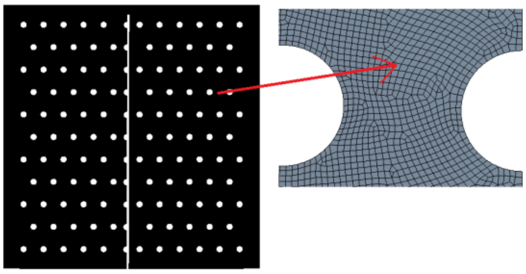

Figure 13: meshing of absorber plate of evacuated flat plate collector design-4

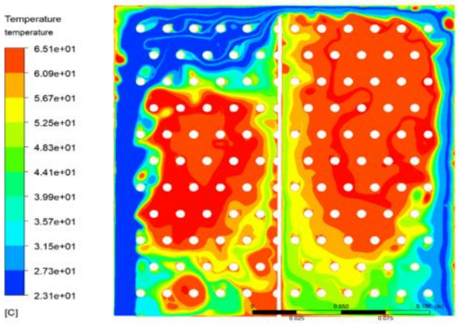

Figure 14: Temperature distribution over the absorber plate of evacuated flat plate collector for proposed design-4

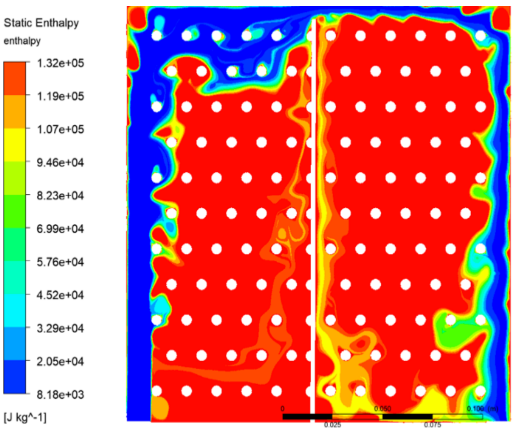

Figure 15: Enthalpy of the absorber plate of evacuated flat plate collector for proposed design-4

CFD Analysis for Design-5

CAD model of absorber plate of evacuated flat plate of design-5 having square hole size 8 mm in ziz-zag pattern with array spacing 7 mm as shown in figure No. 19.

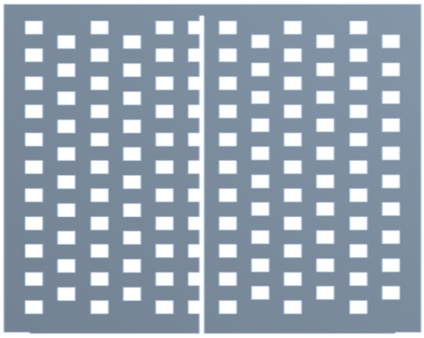

Figure 16: CAD model of absorber plate of evacuated flat plate collector design-5

Meshing: for the design-5 the total nodes are 32527 and total No. of elements are 30158 which are rectangular in shape.

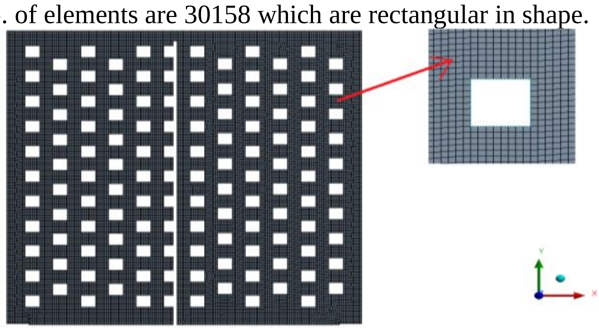

Figure 17: meshing of absorber plate of evacuated flat plate collector design-5

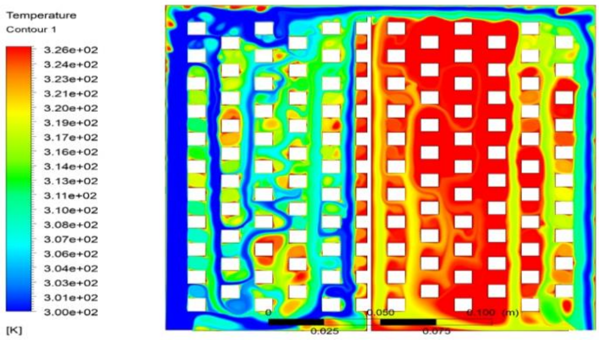

Figure 18: Temperature distribution over the absorber plate of evacuated flat plate collector for proposed design-5

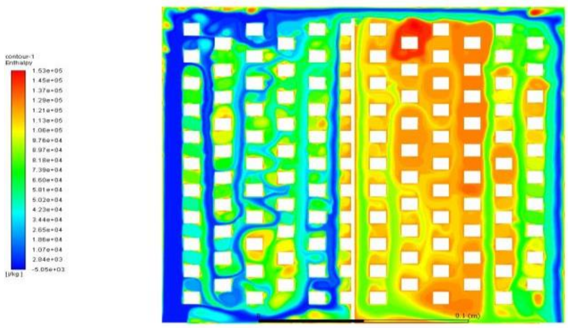

Figure 19: Enthalpy of the absorber plate of evacuated flat plate collector for proposed design-5

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CFD Analysis for Design-6

CAD model of absorber plate of evacuated flat plate of design-6 having polygon hole having side of 4 mm in regular and zig-zag pattern with array spacing 5.5 mm as shown in figure No. 23.

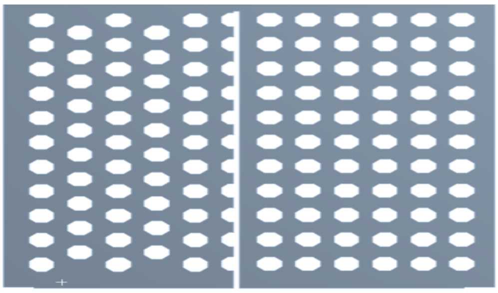

Figure 20: CAD model of absorber plate of evacuated flat plate collector design-6

Meshing: for the design-6 the total nodes are 32729 and total No. of elements are 30537 which are triangular & rectangular in shape.

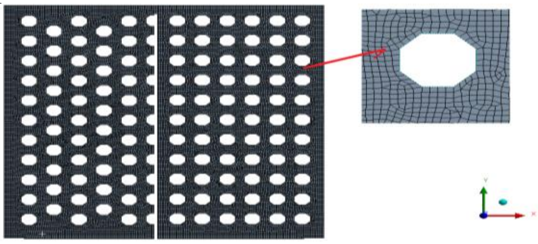

Figure 21: meshing of absorber plate of evacuated flat plate collector design-6

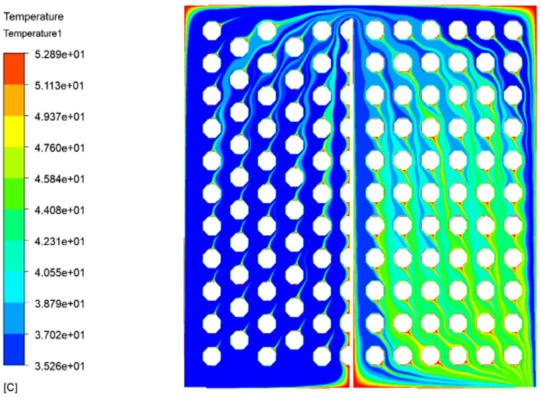

Figure 22: Temperature distribution over the absorber plate of evacuated flat plate collector for proposed design-6

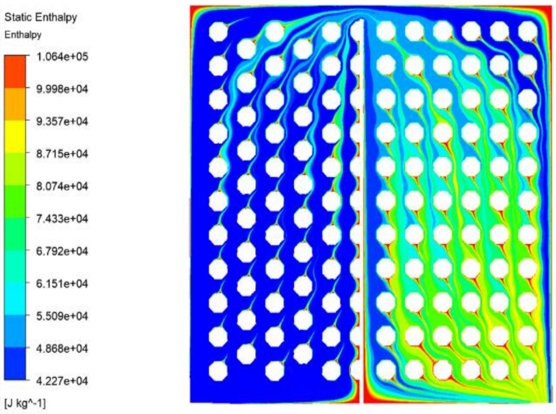

Figure 23: Enthalpy of the absorber plate of evacuated flat plate collector for proposed design-6

IV. RESULTS AND DISCUSSION:

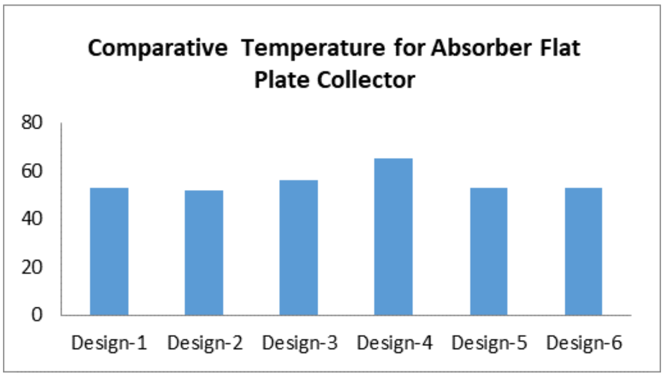

Figure 24 : Comparative result for temperature

It has been observed from above comparative results that design-4 (absorber plate of evacuated flat plate small hole) gives maximum temperature as compared to other designs**.**

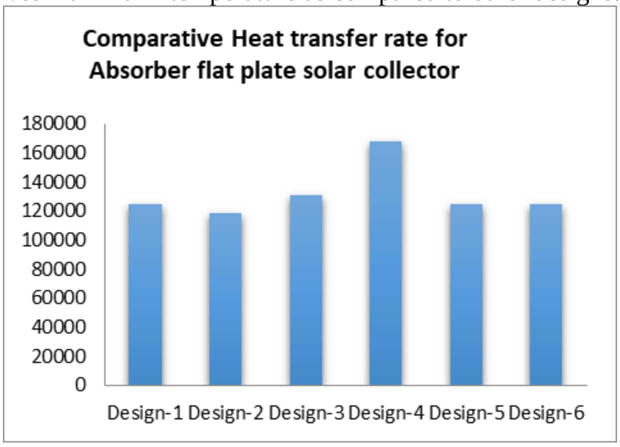

Figure 25: Comparative result for heat transfer

It has been observed from above comparative results that design-4 (absorber plate of evacuated flat plate small hole) gives better heat transfer as compared to other designs**.** Computational fluid dynamics analysis have been performed for various designs of absorber plate of evacuated flat plate collector shown in figure no. 6.49 the Temperature distribution varies from 51.18ºC to 65.15ºC, enthalpy varies from 1.05×10^5J/Kg to 1.31×10^5 J/Kg and the Velocity magnitude varies from 0.364 m/sec to 0.494 m/sec.

V. CONCLUSION AND FUTURE SCOPE

In the present work computational fluid dynamics analysis have been performed for six designs of absorber plate of evacuated flat plate collector to check the temperature distribution and heat generation for better thermal performance and compared results. It has been observe from the above conclusion that the design 4 is more efficient then other proposed designs, the maximum temperature of 65.1 ºC achieved after heating and the enthalpy of this design is 1.31×10^5 J/Kg which is higher than other design. So that it is recommended that the design-4 of the absorber plate of evacuated flat plate collector is best for better heating.

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FUTURE SCOPE

The present work is concentrated to improve the thermal performance of absorber plate of evacuated flat plate collector by changing its design. Though the study is performed with an utmost care then also there is scope for further improvement. Some of the suggestions for future study might be possible are explained.

1. In the present work material of absorber plate is taken as stainless steel but some other materials can also be used for future improvement.
2. In the present work water is taken as working fluid but some other nano-fluids may also be used.

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