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Article

CFD ANALYSIS OF A FLAT PLATE SOLAR COLLECTOR TO IMPROVE HEAT TRANSFER CAPACITY

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Abstract. Low-level and medium-level solar heat systems typically use flat-panel solar heat collectors to absorb solar heat energy, convert it to heat, and then heat the liquid (usually water or air) flowing through them. Communicate. These systems are used in home and industrial applications such as water and heating. The purpose of this work is to provide numerical simulations of solar collectors built for a variety of purposes. To better understand the heat transfer capacity of solar collectors, the tool Computational Fluid Dynamics (CFD) was used in the current diploma treatise. In this paper ANSYS Workbench is used to build a 3D collector that included an air intake, a wavy textured absorption plate, a glass cover plate, and pebbles. ANSYS ICEM is used to build an unstructured grid. The results were obtained using the ANSYS FLUENT program.

Keywords: Solar collectors, Heat energy, Numerical simulations, Heat systems.

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1. Introduction

The most significant energy source in the planet is solar energy. In the absence of an atmospheric layer, the Sun, which has a diameter of 1.39 x 109 (m), emits 1353 (W / m2) on a surface perpendicular to light rays when it is 1.495 x 1011 (m) from Earth. 170 trillion (KW) of solar energy is received by the planet each year, of which 30% is reflected back into space, 47% is transformed to cold thermal energy, and 23% is used for the biosphere's cycle of evaporation and precipitation [1]. For the kinetic energy of wind, waves, and plant photosynthesis, 0.5 percent is employed.

There are several components in the solar energy system. The solar collector, which transmits heat from the sun to the absorber and from the absorber to the fluid, is the most crucial component of these systems. Solar panel modifications are frequently done to improve the efficiency of these systems [2]. The most popular solar collectors for solar space heating and solar hot water systems in homes are flat plate collectors. A standard flat collector is a metal box that is insulated, covered with glazing made of glass or plastic, and has a dark absorber inside. These collectors warm air or liquids to temperatures lower than 80°C.

2. Flat plate collector

Plate Collector, flat the comparatively straightforward flat plate collector has the broadest utility among the several solar collectors designs now under development. In comparison to other types of collectors, it is the simplest and least expensive to build, install, and operate, and its qualities are well recognised. Additionally, it is possible to employ diffuse and pyrheliometer. Flat plate collectors may produce heat at temperatures high enough to heat buildings, hot water, and swimming pools for both domestic and commercial usage [3]. A freezing unit can also be used, especially if reflectors help the sun's incidence. Temperatures between 40 and 100 °C may be reached with ease using the flat plate collector [4]. With a specific surface, reflectors to boost incident radiation, and a highly careful construction employing heat resistant materials, higher working temperatures may be attained.

In Figure 1.1, a typical flat plate collector is seen. A substantial portion of the solar energy that strikes the surface of a high absorption absorber after passing through a transparent cover is absorbed by the panel and transported to a transport medium in a liquid tube for use or storage. To minimise conduction loss, the casing side and the bottom of the absorber are adequately insulated. The liquid tube may be a separate component of the absorbent panel, or it may be welded to the panel. A header pipe with a significant diameter connects the liquid pipe at both ends.

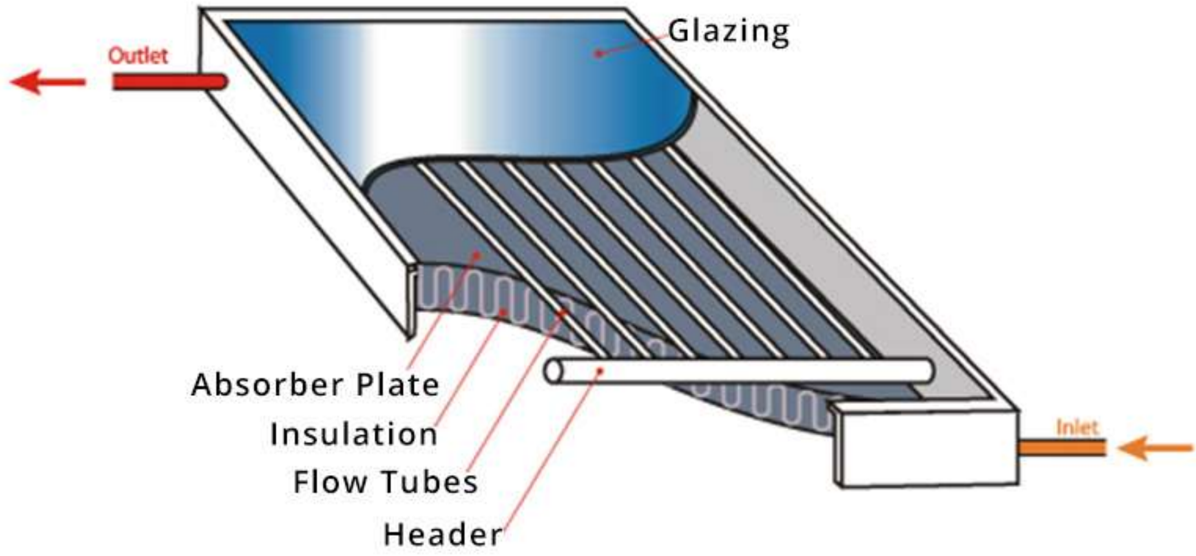

Figure 1.1 A solar flat plate collector

The absorber plate, tubes or fins, thermal insulation, cover strip, glazing, container, or casing are the key parts of a flat plate solar collector.

2.1 Problem Statement

The dimensions of the solar collector used in this investigation are depicted below. The analysis makes advantage of a solar water heater's natural cycle. Each tube is 0.8 metres long, and the corrugated structure has an inner diameter of 0.0127 metres. A pipe with a diameter of 0.0254m and a length of 0.8m is created by gas welding together two pipes that are spaced apart by 0.11m. In order to insulate the area between the absorption tube array and the outer box, rock wool is placed there. The absorption tube array creates an inner box, which is subsequently joined to the outside box. These components are separated by aluminium foil, the box is coated with 0.004-mm transparent tempered glass, and there is a 0.035-mm air gap between the panel and the glass cover. The collector's total dimensions are 1.003 x 0.503 x 0.105 m, and its effective glazing area is 0.5 m^2.[5]

2.2 Geometry And Mesh

The final 3D design is meshed after the geometry is created in the 3D modeler. The completed mesh consisted of 64,000 elements and 68234 nodes. Figure 2.1 shows the completed mesh.

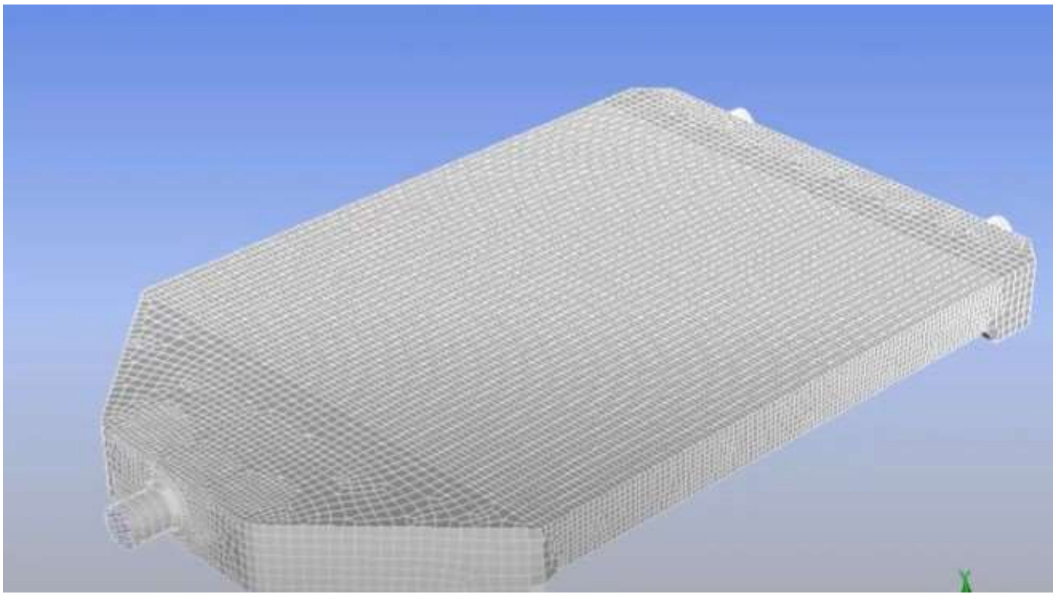
Figure 2.1 The final mesh.

2.3 Setup

Generally, for any analysis some settings need to be configured for the Ansys Fluent simulation process. The setup's solver is configured to be pressure-based, and the formulation for velocity is absolute. Gravity is in the geometry's negative Y-direction and steady time is considered. Figure 2.2 depicts the entire configuration [6].

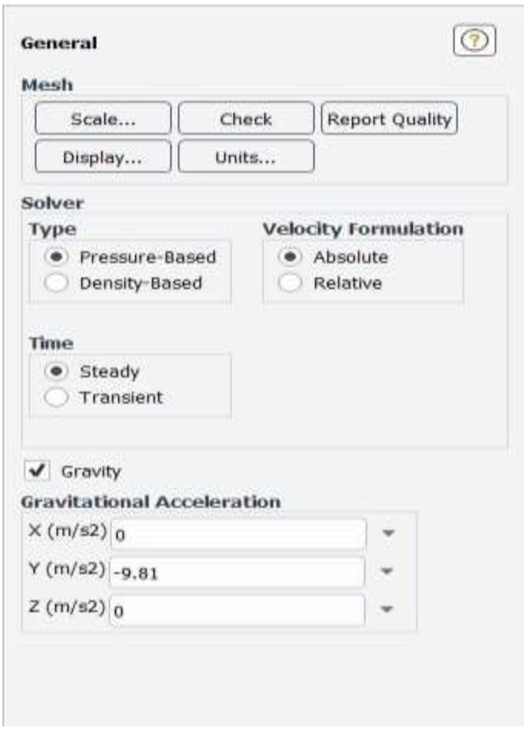

Figure 2.2 Total setup

Turn on the energy equation. Figure 2.3 shows the model constants used in a viable k-epsilon viscosity model (two equations).

The k-epsilon model was first used because it does not algebraically define a turbulent length scale for moderate to high complexity flows. Turbulent kinetic energy is the first quantity (k) transmitted. The rate at which turbulent kinetic energy dissipates is the second reported variable (epsilon).

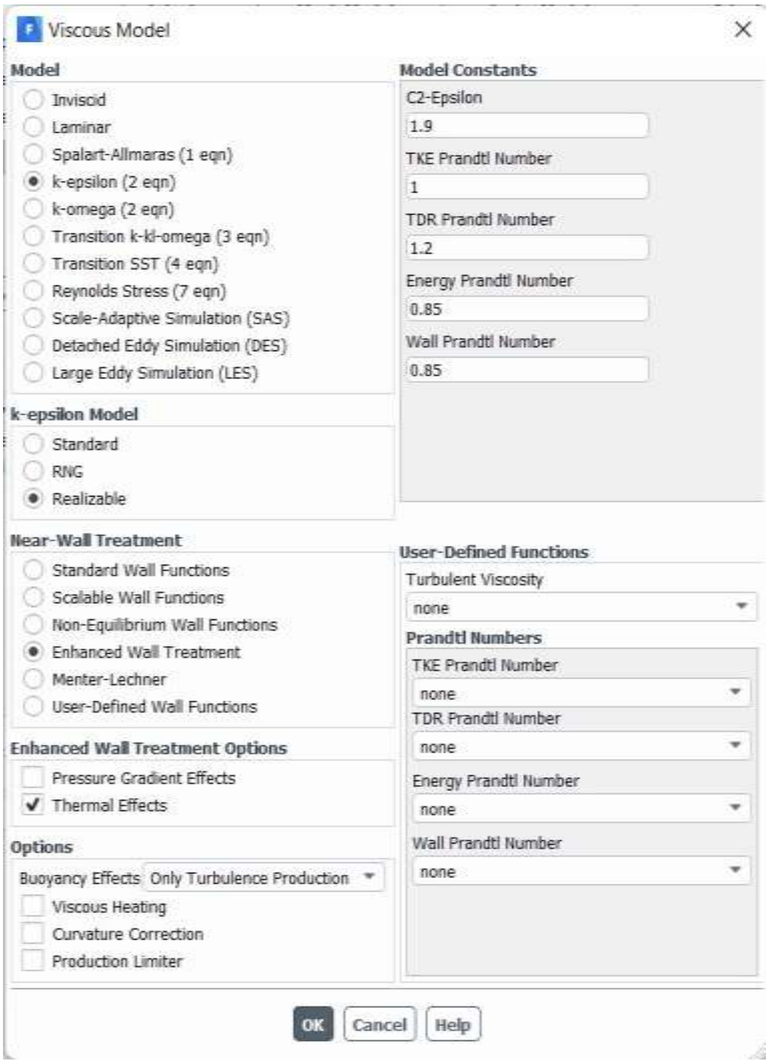

Figure 2.3 Viscous model

The Rosseland radiation model is applied, then solar ray tracing, as seen in Figure 2.4. Illumination parameters are computed using solar calculators. For the sake of this analysis, A place is required for its latitude and longitude positions.

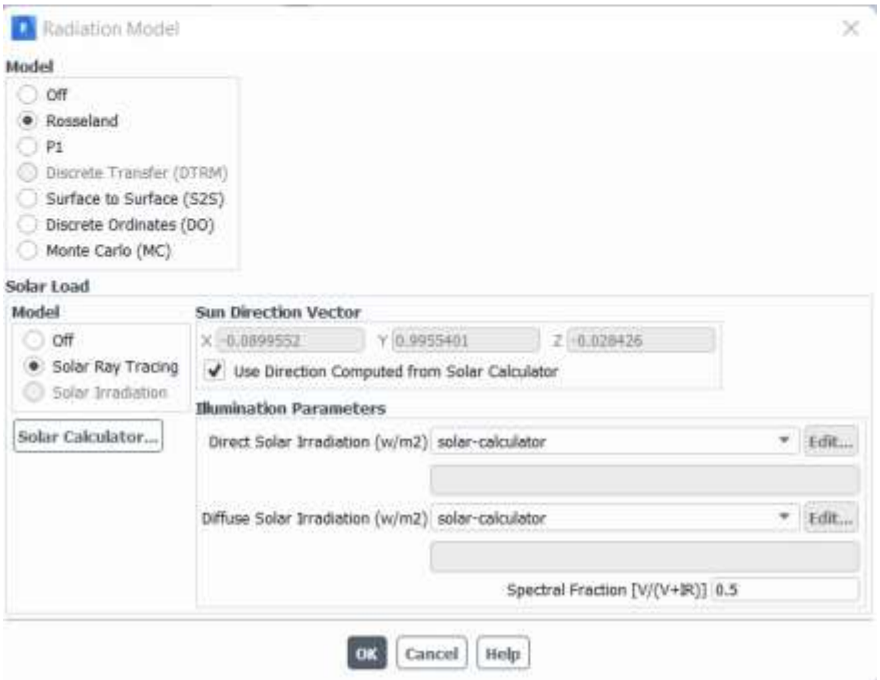

Figure 2.4 Radiation model selection

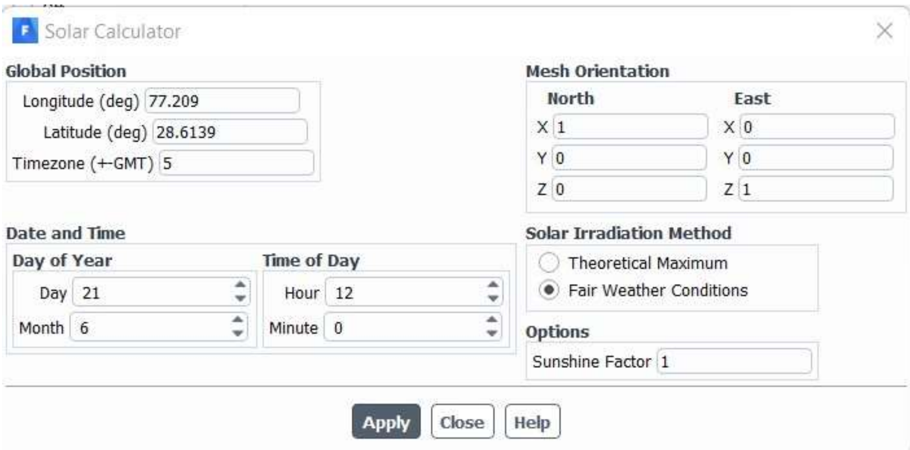

Figure 2.5 Solar calculator

Next step is to select the materials used in the flat plate collector. Generally, the materials used in the collector include copper and glass.

As glass is missing in the fluent data base, aluminium is selected as the material and replace the properties of aluminium with the properties of glass as shown in figure 2.6.

The next step is to set up the boundary conditions of distinct parts of the solar flat plate collector namely absorber plate, inlet, collector, and the glazing. For the analysis, the following boundary conditions are used:

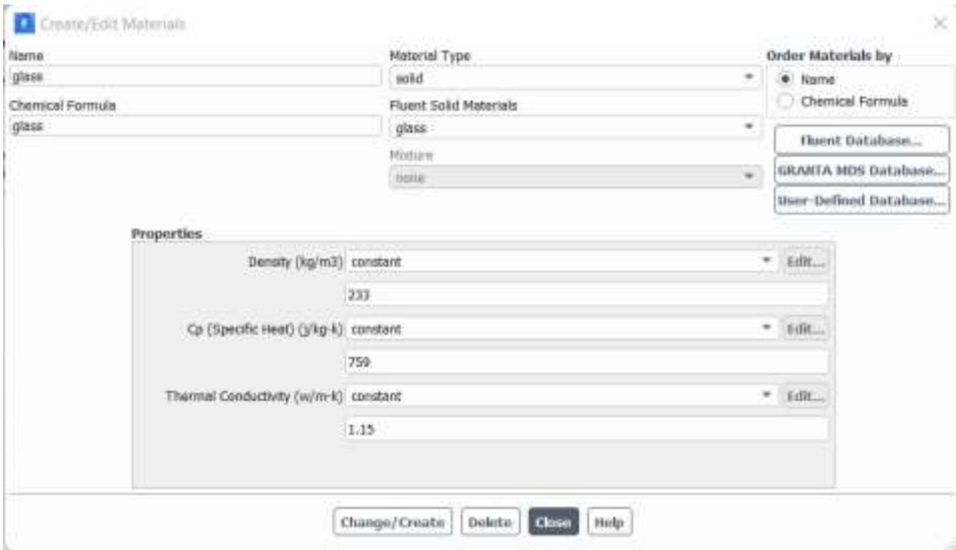

Figure 2.6: properties of glass

1. The absorber plate is of copper and the absorptivity is considered as 0.9 in both visible and infrared regions as shown in figure 2.7 A and figure 2.7 B

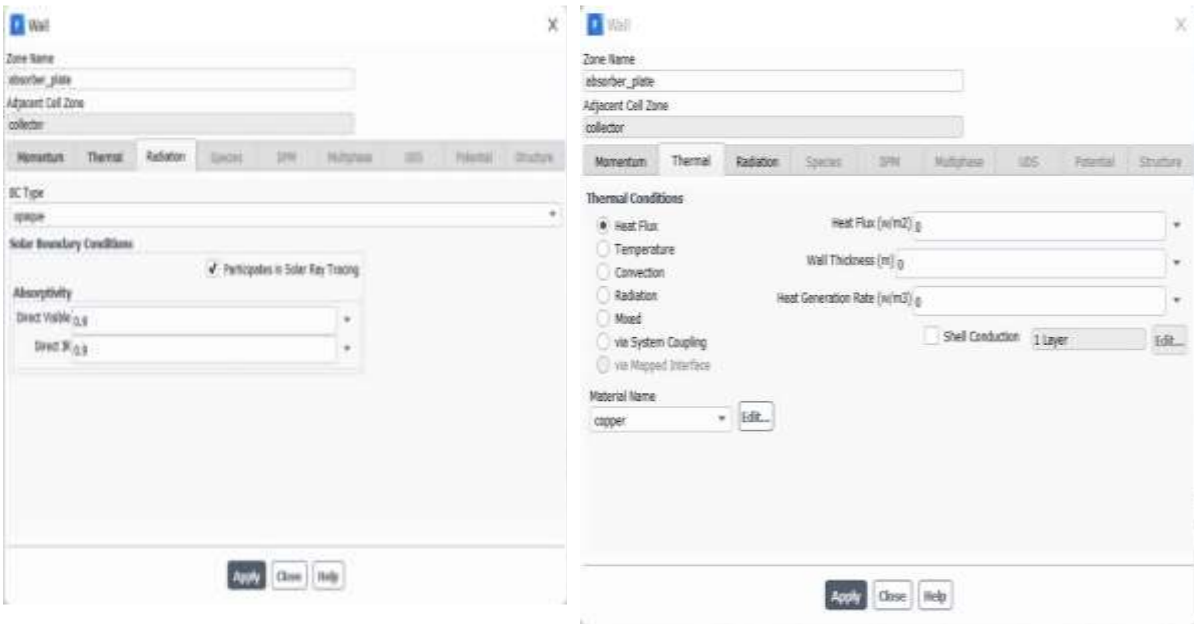

Figure 2.7 Boundary conditions of absorber plate a) Radiation setup b) Thermal setup

2. The glazing is made of glass and considered as a semi-transparent substance involving in the solar ray tracing. The absorptivity is set as 0.1 in IR and visible regions and transmissivity is considered as 0.9. The image indicating these parameters is shown in figure 2.8.

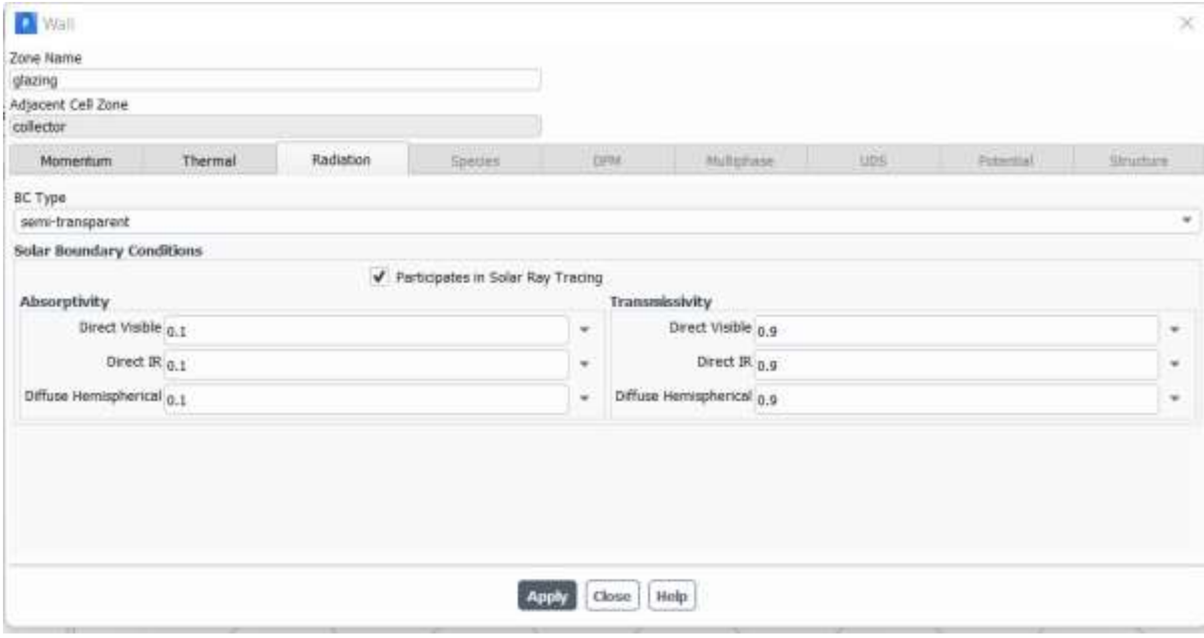

Figure 2.8 Glazing boundary conditions

3. Setting up the inlet as a mass flow inlet followed by the selection of direction specification as "Normal to Boundary" and the mass flowrate as 0.05 kg/s at a temperature of 25°C as shown in the figure 2.9.

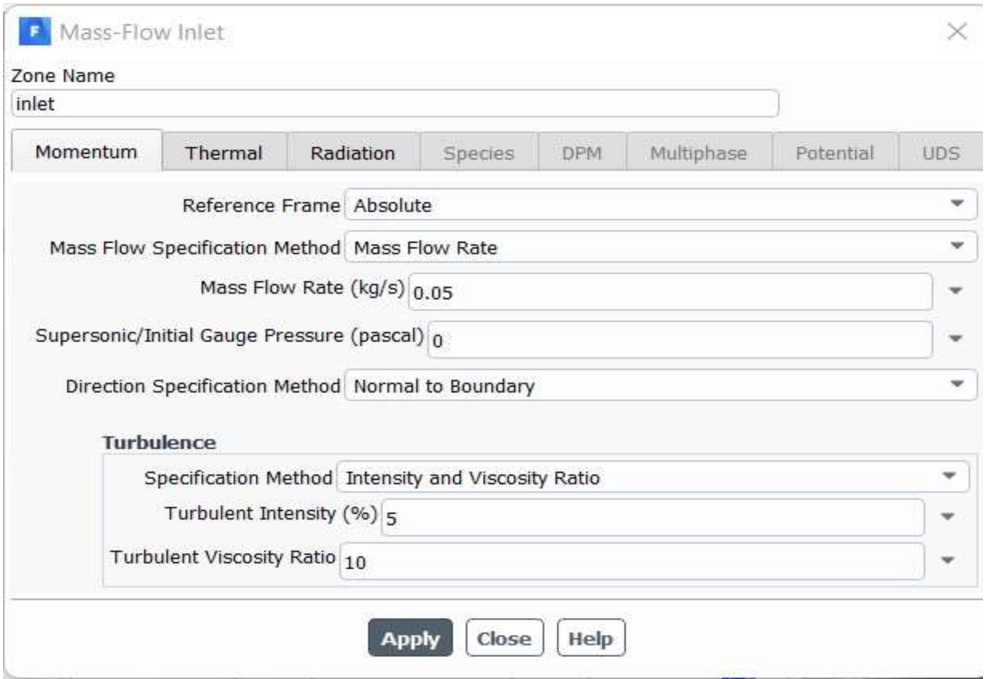

Figure 2.9 Boundary conditions of inlet.

4. Setting the outlet temperature as 25°C.
5. Finally selecting the wall material as aluminium undergoing convection at free stream temperature of 25°C and with a heat transfer coefficient of 5 W/m²K. The entire parameter selection is shown in the figure 2.10

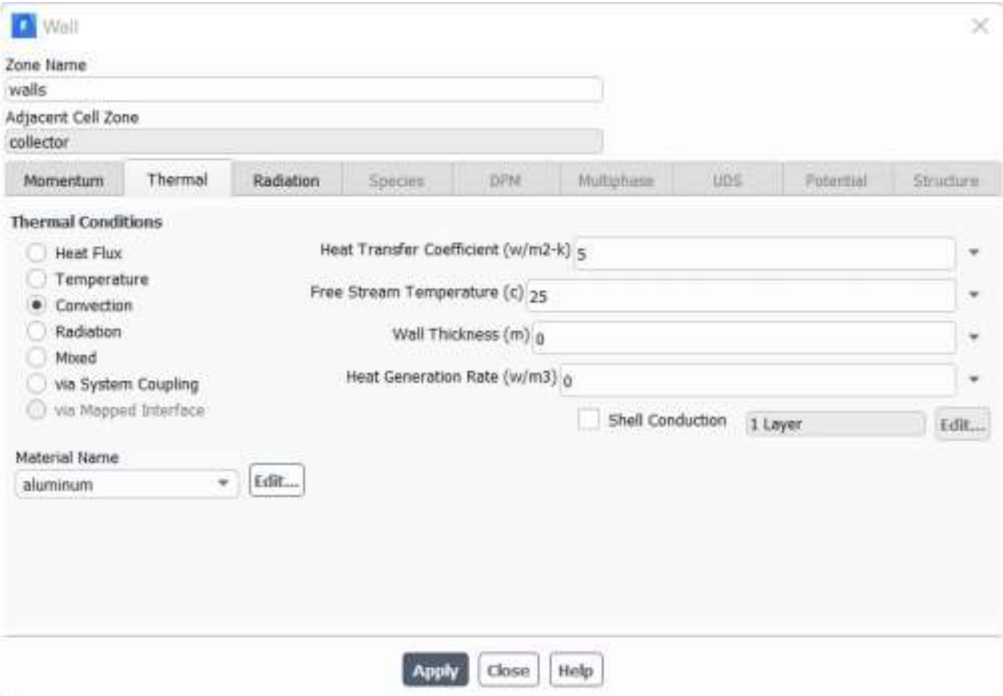

Figure 2.10 Boundary conditions of the wall.

The next step is to set the reference values and reference zones. The reference zone is considered as the collector and the values are computed from inlet (Figure 2.11)

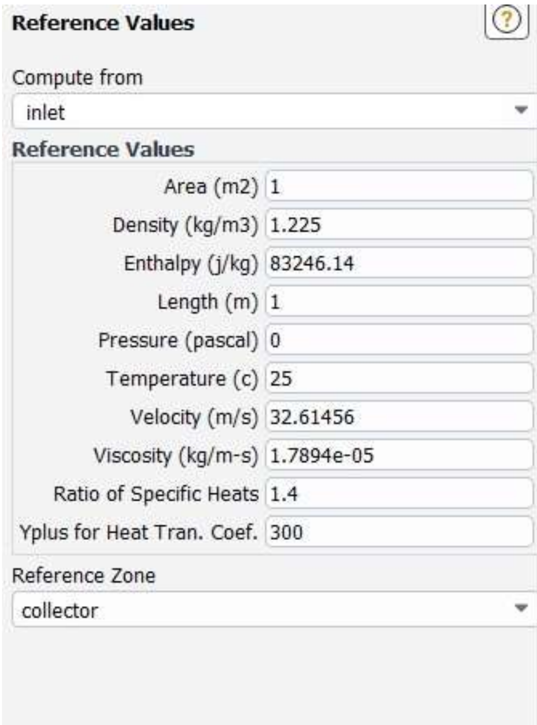

Figure 2.11 Reference values.

The next step includes the selection of the solution methods. For this analysis Green-Gauge node based gradient solver is used under SIMPLE scheme and setting all the values to be considered as second order for more accuracy in the results as displayed in figure 2.12.

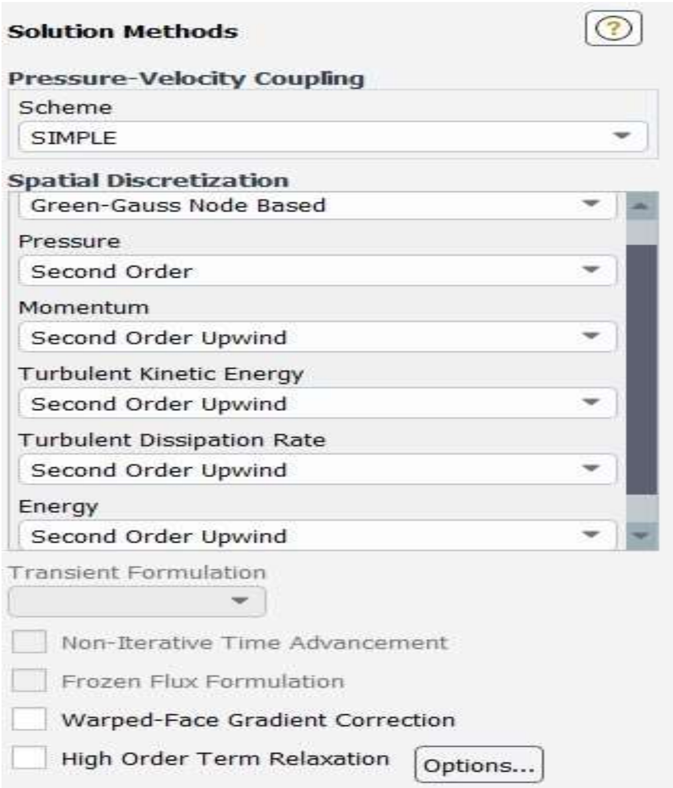

Figure 2.12 Solution methods.

After setting up all the above schemes, the solution must be initialized using two methods. hybrid or standard. The standard initialization is used for the steady state simulation for both the solvers, pressure based, or density based, and improve the convergence robustness of the solution. Therefore, the same is used in the present study.

3. Results And Discussion

After 4500 iterations of calculation, various residuals are obtained which include velocity in x, y, and z directions, continuity, turbulent kinetic energy, and energy. The residual of the present analysis is shown in the figure 3.1.

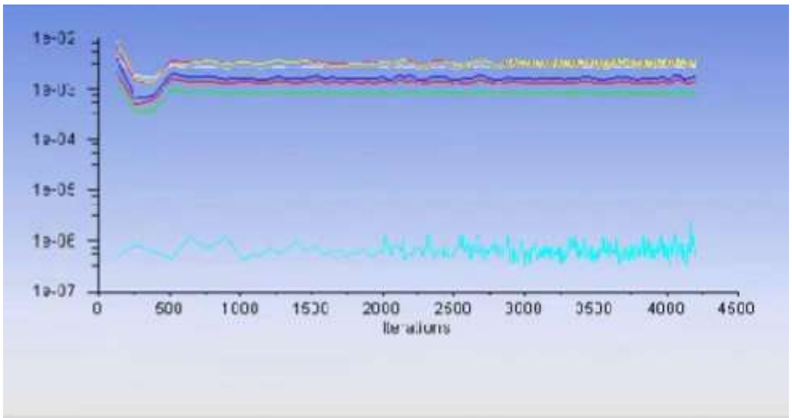

Figure 3.1 Residuals of all iterations.

Now to get the variation of properties at different points on the solar flat plate collector, contours are used. For the present CFD analysis of the solar flat plate collector, various contours are used. The various aspects of contours include of temperature, pressure, IR solar flux absorbed, velocity and the turbulence [7].

In the figure 3.2 , The contours of absorbed IR solar flux is shown. It can be observed that the flux is high at some points of sbsorber plate i.e the fins which are to be heated to heat the air present under it. So the flux is higher at the fin areas and minimum at other spots.

In the figure 3.3, The contours of pressure are shown and by observing the contour lines, It is to be noted that the entire apparartus is at same pressure as it is closed and also in horizontal position.

In the figure 3.4, The contours of temperature is shown and it is observed that the temperature is high at the fins where the absorber plate transfer its heat flux and the remaining area is at minimal temperature. The temperature difference can be observed and it indicates the usage of flat plate collector can be encouraged for house hold applications in near future[8].

Figure 3.5 and 3.6 are showing the contours of turbulence energy and the velocity of the flat plate collector.

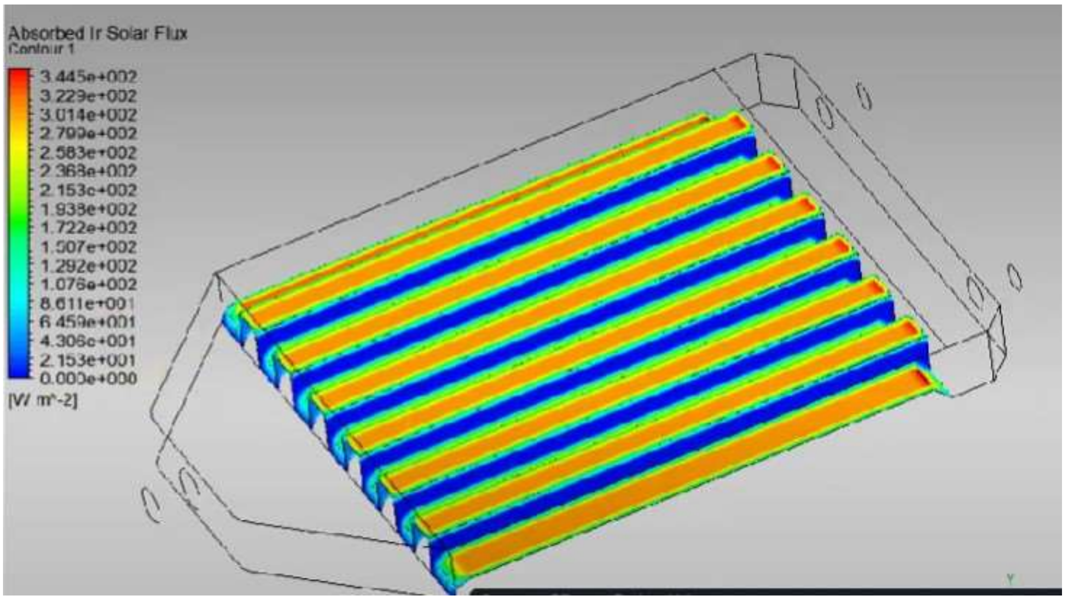

Figure 3.2 Contours of absorbed solar flux.

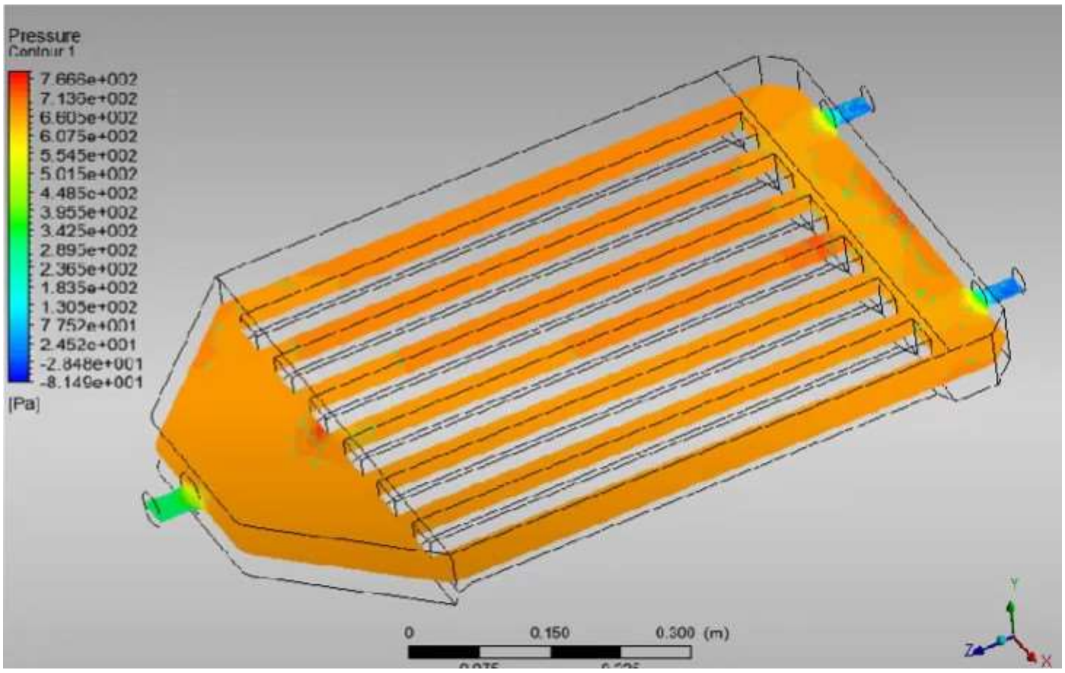

Fig 3.3 Contours of pressure.

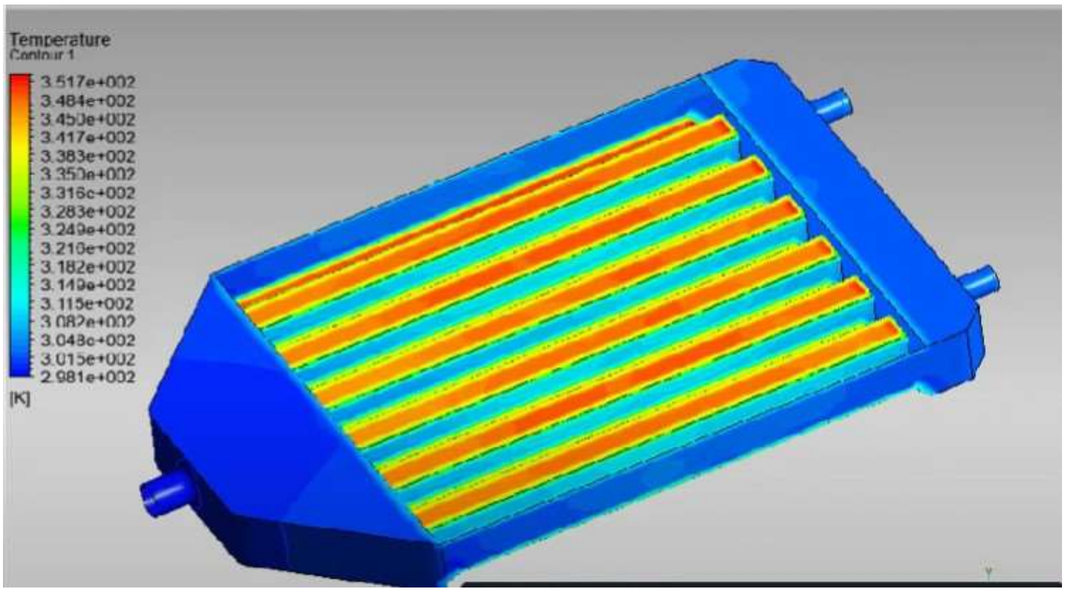

Figure 3.4 Contours of temperature.

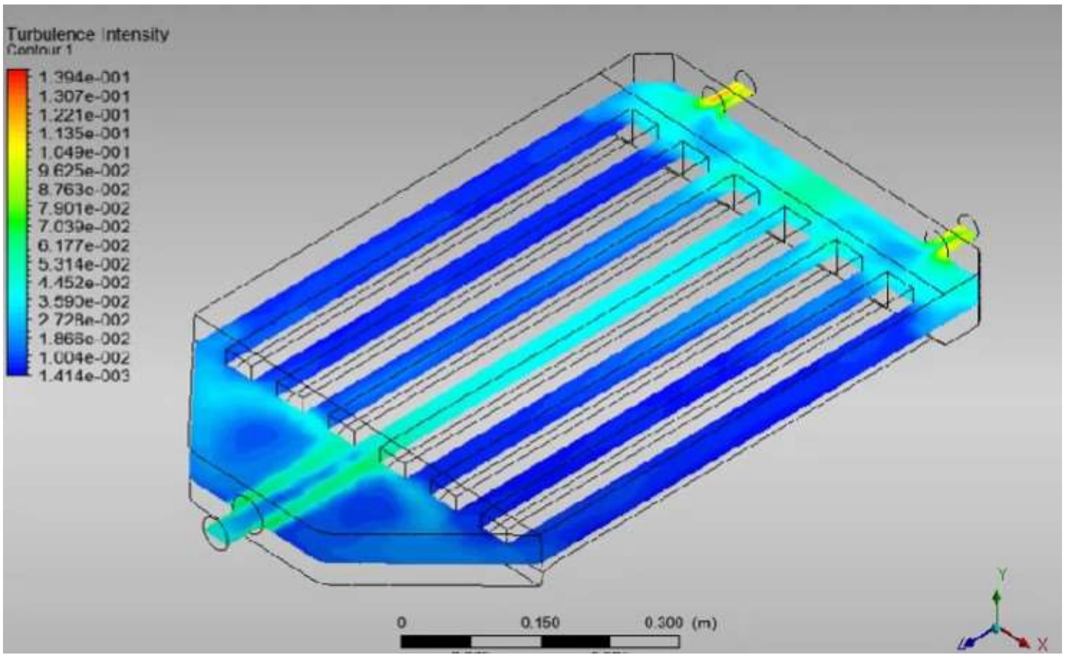

Fig 3.5 Contours of Turbulence.

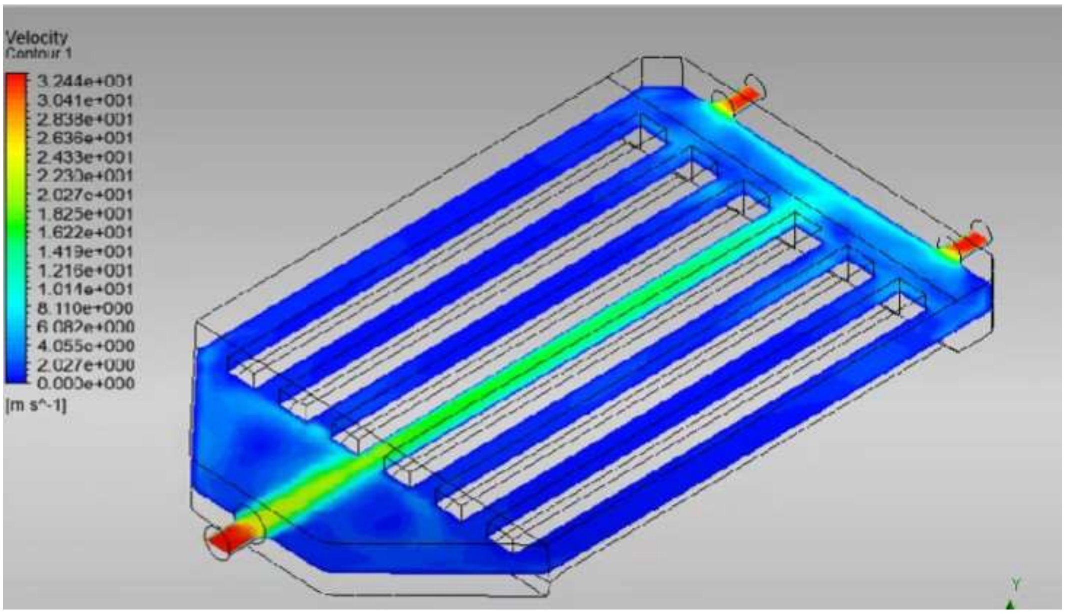

Figure 3.6 Contours of Velocity.

4. Conclusion

To fulfil the rising energy demand for daily home demands, solar energy is crucial. In order to model the flat plate collectors and forecast their performance in any location, substantial research should be done for its geographical parameters. The flow rate and temperature distribution in the solar collector were investigated numerically and experimentally. Using CFD models, the impact of absorption plate effects and tube geometry on flow and heat distribution are noticed effectively. The working fluid's improved capacity to absorb heat results in a reduction in the absorber's ambient temperature and an increase in collector performance. The measured temperature difference has been found to be a reliable predictor. It also indicates that the Flat plate collectors can also be used to offset non-renewable resource energy use in the near future.

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