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Computational fluid dynamic analysis of solar chimney design

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Abstract - *For both configurations with and without the geothermal mechanisms, the CFD analysis of such a solar chimney is performed using ANSYS CFX. Investigations are conducted into the typical room temperature, air flow rate, and radiation level. Moving away from the left glass, where solar radiation is incident, reduces the average radiation intensity in the room. Radiation levels are lowest at the room's centre. Geothermal design 3 has the lowest observed average room temperature, which is roughly 299K. With a magnitude of roughly 309.69K, the generic design (without a geothermal mechanism) produces the greatest average room temperature. The rate of mass flow decreases with the inclusion of a geothermal process.*

Key Words: *CFD, Comfort thermal, naturally ventilated, solar chimney*

1. INTRODUCTION

1.1 VENTILATION

In any closed environmental system, ventilation involves the input and outflow of air. There may or may not be an air purification component. To control interior humidity, remove impurities, and maintain a reasonable temperature, a structure must have proper ventilation. Inhaled air quality has a big impact on how comfortable people are and how productive they are.

Humans need at least 1.2 litres of air to breathe per second, however more is preferable for comfort. This allows for appropriate O2 circulation and CO2 dilution. Proper ventilation helps sustain temperature in cases of extreme heat gains. The following factors affect a building's thermal comfort and interior air quality.

1.2 Natural ventilation (1.1.1)

Natural ventilation involves the circulation of air via apertures like windows and doors. To allow air to flow, an intentional aperture has been made. The pressure differential between inner and exterior air is what causes air to move. The natural ventilation may be influenced by wind or by temperature.

Building quality and thermal comfort are determined by the following elements.

1. Positive pressure and negative pressure are produced in a ventilation system powered by the wind. Building pressure is positive on the windward side and negative on the leeward side. Air flow is caused by the pressure difference between these two areas.

2. In ventilation systems driven by temperature, a high temperature creates a stacking effect. The building's interior air temperature rises as cooler exterior air enters at a faster rate. As a result, cool air is brought in from the outside, causing airflow.

1.3 Mechanical ventilation (1.1.2)

Mechanical fans are used throughout the mechanical ventilation process. These mechanical fans are installed on ducts, walls, ceilings, or both. These mechanical fans' main function is to make it easier for air to enter and leave the area. When the weather is warm and muggy, infiltration is used. A constructive pressure system places the room under positive pressure, and the room air escapes through envelope leaks or other openings. A negative pressure system places the room under negative pressure, and the room air is made up by sucking air in from the outside. [6]. The mechanical ventilation system should be balanced "where air supply and exhausts have been evaluated and changed to satisfy design standards." [6].

2. PROBLEM FORMULATION

The present work is concerned with carrying out two-dimensional simulations on an solar roof chimney, through which air flows. The inlet and outlet is defined of length

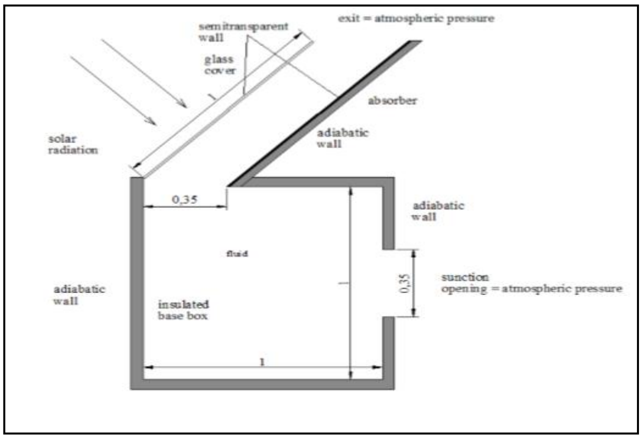

Figure 5.2 Schematic of inclined solar chimney [9]

3. MESHING

The model is meshed using fine sizing and brick elements. The growth rate is set to 1.2, inflation is set to normal and number of layers set to 5. The meshed model of computational domain is shown in figure 5.4 below.

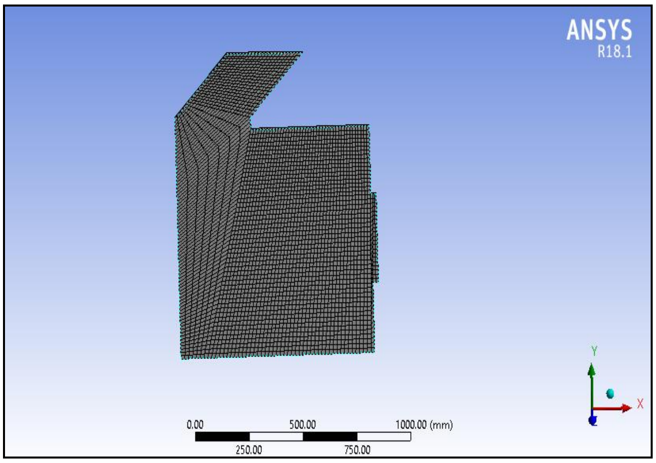

Figure 5.4 Meshing of inclined chimney

Without a geothermal mechanism, an inclined solar chimney

The findings from a CFD analysis of an inclined solar chimney without a geothermal mechanism are discussed in this section.

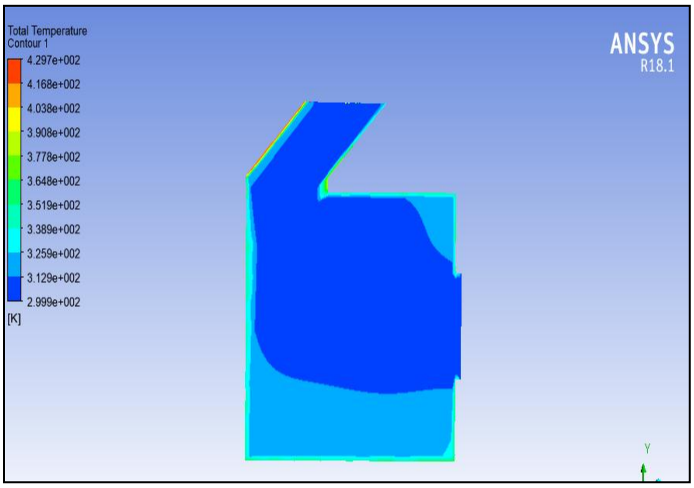

Figure 6.1 Temperature plot of an inclined solar chimney without a perforated plate.

The temperature map created by CFD analysis is shown in Figure 6.1. The plot shows that the temperature is higher close to the absorber plate and the glass. Heat is dispersed throughout the domain by radiation. The investigation made use of multiband spectral modelling with Monte Carlo radiation modelling. The room has a higher temperature in the corners than it does in the centre. Convective heat transfer caused by airflow in the dark blue zones is to blame for this.

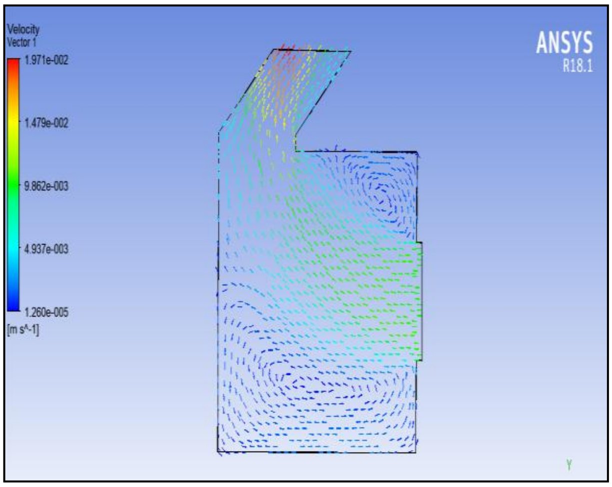

Figure 6.2 Velocity vector for inclined solar chimney without perforated plate

The velocity vector plot is shown in Figure 6.2. Two places where vortex development is shown in the plot. The bottom left corner is the first zone, and the top right corner is the second zone. The area where air flow is straight from entrance to exit is where convective heat transfer is greatest. This kind of air flow raises temperatures in vortex zones, as seen in Figure 6.1.

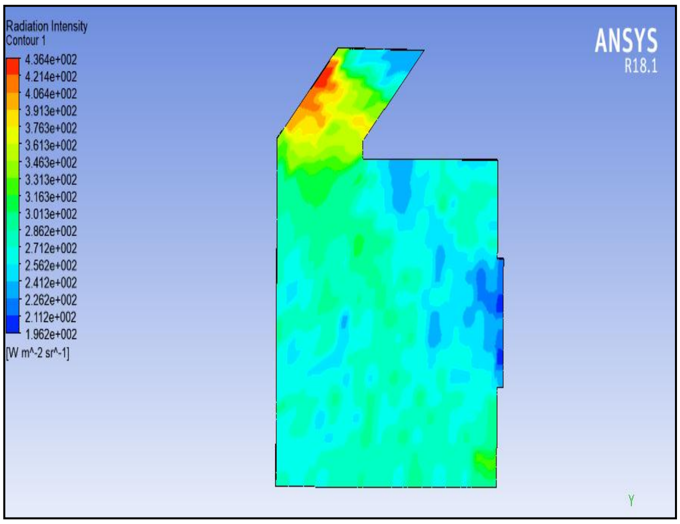

Figure 6.3 Radiation intensity of inclined solar chimney

Figure 6.3 depicts the radiation intensity plot. Due to the direction of incident radiation, the map reveals a higher intensity of magnitude 436.4 W/m2 in the regions near the incidence glass surface and in the bottom right corner.

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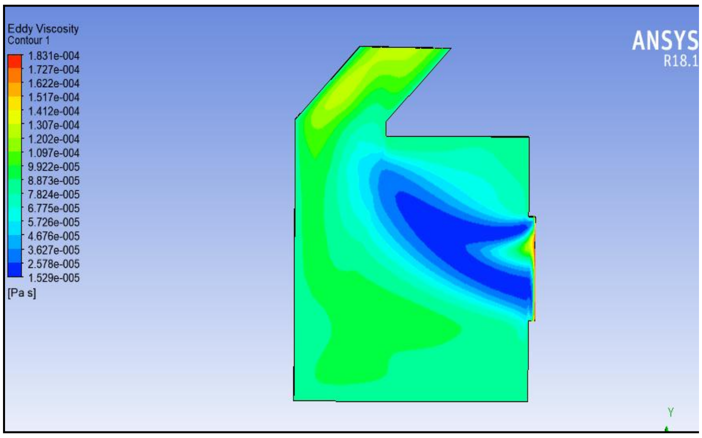

Figure 6.4 Eddy viscosity for inclined solar chimney without perforated plate

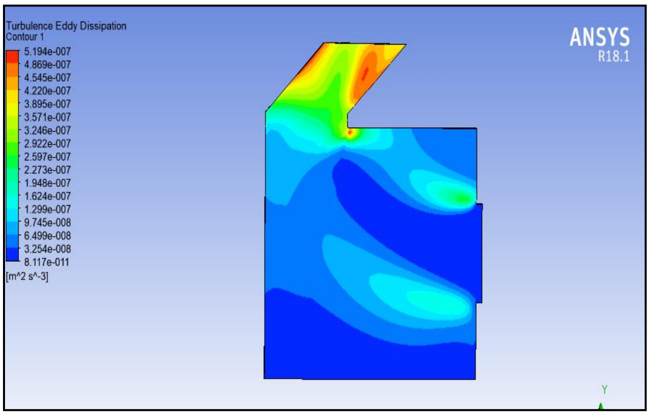

Figure 6.5 without a perforated plate, turbulence eddy dissipation for an inclined solar chimney

The temperature is lower in sections where the air flow vectors are straight (without swirl) than in parts where the air flow vectors are swirled or turbulence is induced. The same can be seen in the eddy viscosity plot, which exhibits high values in places with high air turbulence.

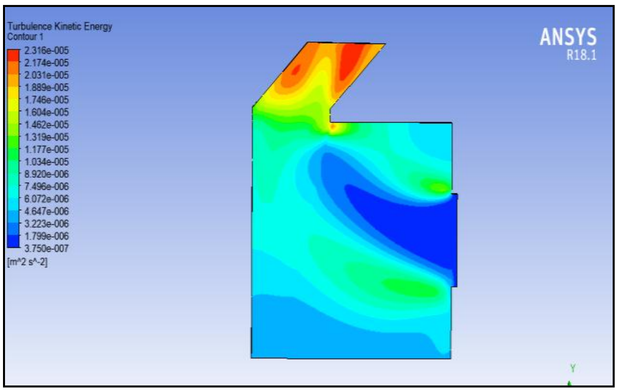

Figure 6.6 Turbulence kinetic energy for inclined solar chimney without perforated plate

Turbulence's kinetic energy is greatest near the exit and near the absorber plate and glass surface where sunlight is incident. Figure 6.7 depicts the pressure plot. Suction (negative pressure) is depicted on the pressure plot in the region between the glass (on which the sunrays are incident) and the absorber plate.

Table 6.2: Temperature and heat transfer table

Geometry Details	**Inlet Temp (K)**	**Outlet Temp (K)**	**Temperature Difference (K)**	**Average temperature (K)**
Without geothermal	300	310.33	10.33	309.69
With geothermal design 1	295	310.67	15.67	300.41
With geothermal design 2	295	311.16	16.16	299.42

Table 6.4: Heat extracted

Geometry Details	**Average Mass Flow (Kg/s) * 10^{-5}**	**Temperature Difference (K)**	**Heat extracted (Joules)**
Without geothermal	8.23488	10.33	.854
With geothermal design 1	5.78872	15.67	.911
With geothermal design 2	5.78872	16.16	.939

The heat extraction comparison among 3 different design configurations is shown in figure 6.26 below. The comparison graph shown highest heat extraction rate for geothermal design 2 followed by geothermal design 2 and minimum heat extraction is observed for generic design.

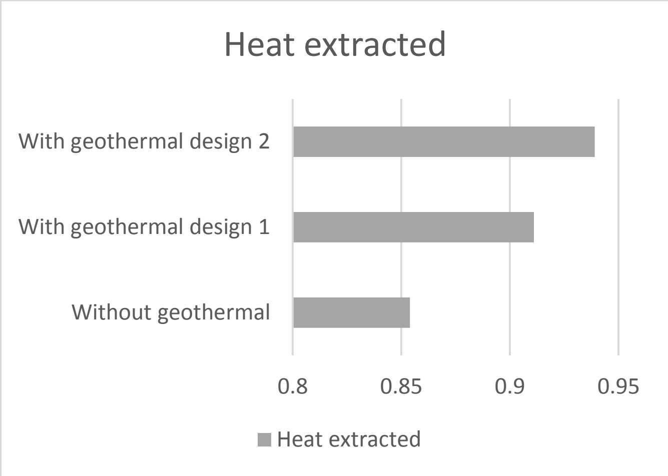

Figure 6.26: Heat extraction comparison

4. CONCLUSION

1. With and without the use of a geothermal mechanism, the solar chimney's CFD analysis is carried out using ANSYS CFX. It looks at radiation intensity, average room temperature, and airflow rate.

2. Moving away from the left glass, where solar radiation is incident, reduces the average radiation intensity in the room. Radiation levels are lowest at the room's centre.

3. With a magnitude of roughly 299K, geothermal design 3 has the lowest average room temperature.

4. A magnitude of roughly 309.69K is recorded for the generic design (without a geothermal system) as the greatest average room temperature.

5. With the addition of a geothermal mechanism, the mass flow rate decreases. Despite the fact that the cooling obtained is more than with a generic design.

6. Geothermal design 2 extracts the most heat, while generic design extracts the least.

7. Geothermal design 3 achieves the highest in-room cooling, whereas generic design achieves the least.

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