CFD Analysis of Solar Chimney Ventilation with Geothermal Mechanism

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Abstract— The solar chimney is a natural ventilation technique that has the potential to save energy use in buildings as well as maintain comfortable indoor quality. This research aims to study inclined solar chimney with geothermal mechanism using CFD technique. A two-dimensional symmetric model using the RNG (Re-Normalization Group) k−ε turbulence closure is simulated. The discrete ordinates non-gray radiation model is used to implement the radiative-transfer equation. To simulate solar irradiation, the solar ray-tracing algorithm is employed. The software used for modeling is Creo 2.0 and for analysis ANSYS CFX is used.

Keywords: Inclined Solar Chimney, Passive Ventilation, CFD, Geothermal Mechanism

I. INTRODUCTION

Ventilation can be defined as the supply and removal of air, to and from any space, in order to control the level of air contaminants, humidity or temperature within that space. Air may or may not undergo conditioning during the process of ventilation. Since ventilation in buildings plays a major role on the health, comfort and productivity of their occupants, ventilation standards have been issued in many countries around the world. It is estimated that the minimum volume of fresh air needed for the purpose of breathing is approximately 1.2 liters per second per person but for comfort purposes, it is essential to supply more than this minimum amount in order to meet the occupants' oxygen requirements, for dilution of odors, dilution of carbon dioxide concentration and to minimize the increase in air temperature in case there are extreme sensible heat gains. A ventilation system in a building is an important design criterion as it helps to improve thermal comfort and the indoor air quality. The latter is dependent on the following factors:

1) Climatic parameters including humidity, velocity of air, temperature and levels of air contaminants.
2) Parameters related to the occupants such as moisture, carbon dioxide, odours and tobacco smoke.
3) Parameters related to the building and outdoor sources such as formaldehydes, volatile organic compounds, radon, biological agents and airborne particulates.

The ventilation process in buildings can either take place naturally or mechanically. Natural ventilation is dependent on wind or thermal buoyancy for the movement of air while an external power input is required for mechanical ventilation

II. LITERATURE REVIEW

Ohanessian and Charters [1] inspected the impacts of coating and divider thickness on the changed Trombe-Michel divider amid the winter in Melbourne, Australia utilizing limited distinction reenactment. Around a similar period, Akbarzadeh et al. [2] directed investigations with an altered Trombe divider at a building rooftop in the University of Melbourne, Australia. Likewise, Das and Kumar [3] tried different things with a level plate solar chimney utilized to dry agrarian items.

Awbi [4] gave a presentation of the different strategies for common ventilation and analyzed the impacts of wind and solar-incited ventilation hypothetically utilizing vertical and slanted solar chimneys. Results demonstrated that the impact of wind was more prominent than the stack impact while the slanted solar chimney performed better because of its more prominent uncovered surface area.

Aboulnaga [5] did hypothetical investigation on a typical inhabitant working in Al-Ain city, UAE. The solar chimney's profundity and tendency points were differed. Results gave an ideal tendency edge of 35° and a solar chimney profundity of 0.20 m.

Khedari et al. [6] inspected the impacts of the altered Trombe divider in a room. Results demonstrated that a greater air hole or a darker shading on the divider prompted more wind stream.

III. OBJECTIVES

The aim of this research is to incorporate perforated plate in design of solar chimney and geothermal mechanism to analyze its effect on ventilation using ANSYS CFX software.

IV. METHODOLOGY

The analysis is conducted using Finite Element Method using ANSYS CFX software. The CAD model of computational domain of length 1m and width 1m is defined with an opening of .35m for air inlet (suction)on right wall and .35m on top ceiling for air outlet as shown in fig 1. The computational domain of chimney is modeled in CREO 2.0 software for inclined solar chimney with geothermal mechanism. The CAD model is imported in ANSYS design design modeler as shown in figure 2.

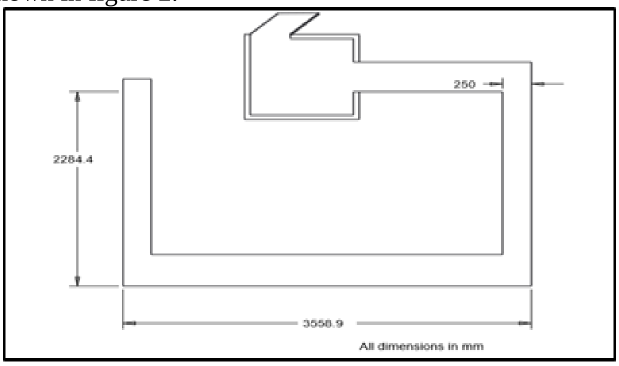

Fig. 1: Schematic of inclined solar chimney with Geothermal Heat Exchange Design

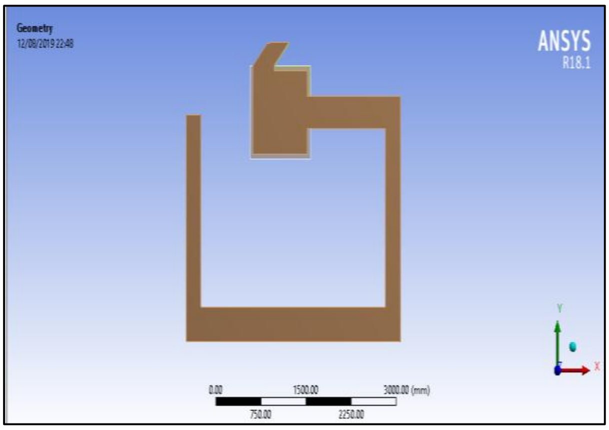

Fig. 2: Imported CAD model of inclined solar chimney with Geothermal Heat Exchange

The meshing work was accomplished on commercially available ANSYS meshing software. The geometry created was imported in ANSYS meshing. The meshed domain consisted mostly of uniform sized cells. Fine meshing was completed near the absorber plate walls in order to solve the concerned governing differential equations accurately in the laminar sub-layers at these regions. The mesh size increased towards the center. The size of the grid was constant lengthwise in entrance and exit sections of the duct as shown in figure 3.

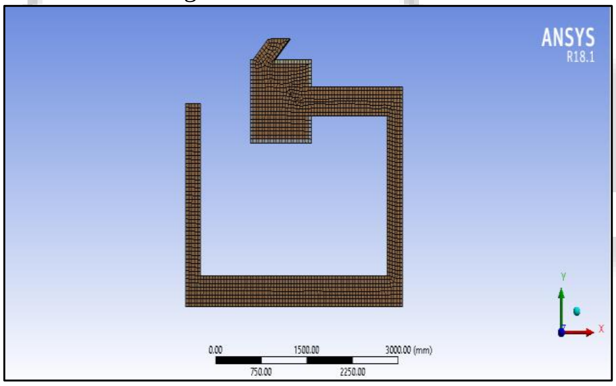

Fig. 3: Meshing of Computational Domain

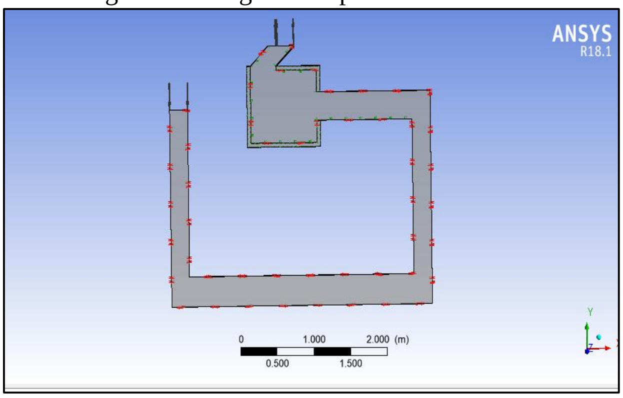

Fig. 4: Loads and Boundary Condition

The domain is defined as fluid. Reference pressure is set to 1atm. Two variable k-epsilon turbulence model is set for analysis and inlet velocity is varied. Fluid is taken as air. Radiation model is set. Different domains i.e. absorber plate, glass, insulation is defined. For air domain air inlet, air outlet and symmetry boundary condition is defined similarly for glass domain heat flux and symmetry is defined. Interface wall between air absorber and air glass interface is generated with conservative interface flux as heat transfer. RMS residual values are set to 1e-4 and maximum iterations are set to 200.

V. RESULTS AND DISCUSSION

CFD analysis of inclined solar chimney is conducted using ANSYS software. The contours of temperature, velocity are plotted as shown in next section.

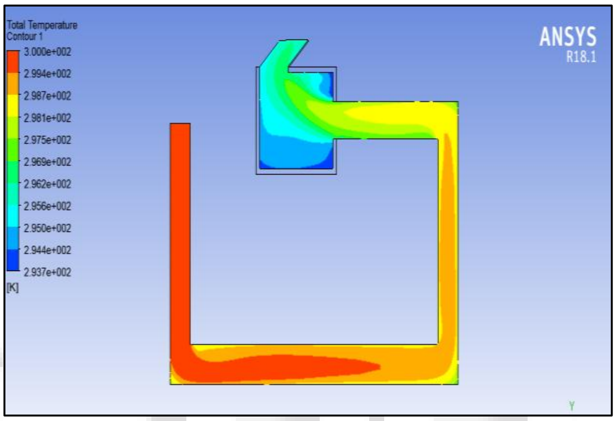

Fig. 5: Temperature plot of geothermal mechanism

The temperature plot of geothermal mechanism with inclined chimney is shown in figure 5 above shows high temperature on left tube and reduces while passing through mid- portion of geothermal tube, the reduction in temperature is noticed by red contour changing to yellow colored contour which further reduces to 296K in room as shown by green colored contours.

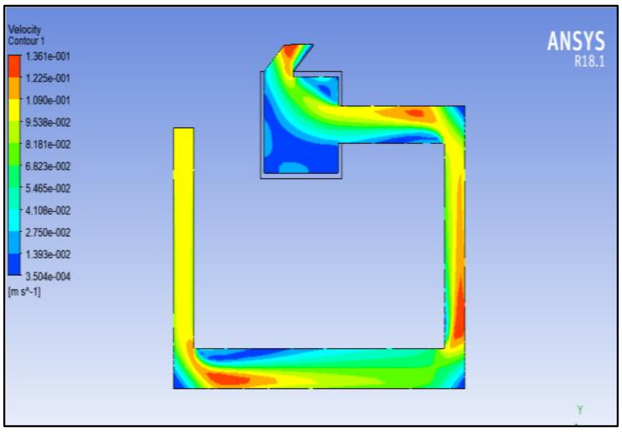

Fig. 6: Velocity plot of geothermal mechanism

Geometry Details	Inlet Temp (K)	Outlet Temp(K)	Temperature Difference (K)	Heat Transfer ($Q = mC_p\Delta T$)
Without geothermal	300	301.3	1.3	1.070
With geothermal	300	295.9	4.1	2.380

Table 1: Output Parameters

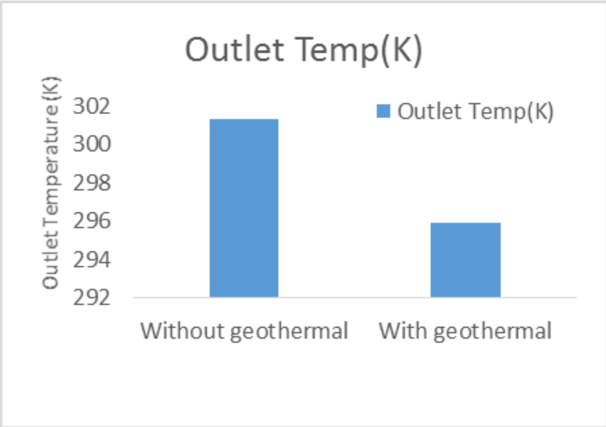

Fig. 7: Outlet Temperature comparison

Figure 7 above shows outlet temperature comparison without geothermal mechanism and with geothermal mechanism. As its evident from figure above the outlet temperature achieved with geothermal heat exchange mechanism is lower by about 5 degrees thus provides significant cooling.

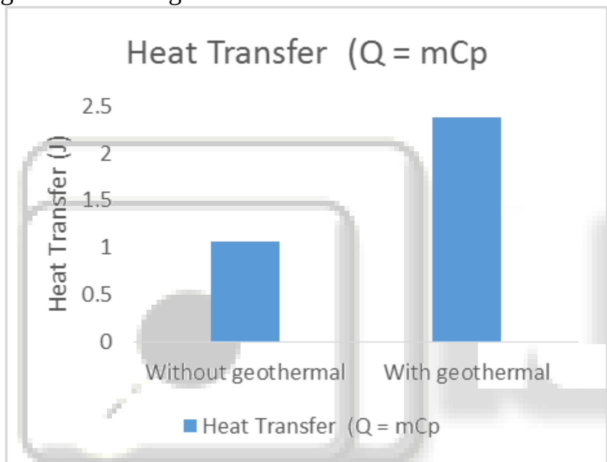

Fig. 8: Heat transfer rate comparison

Figure 8 above shows heat transfer rate comparison without geothermal mechanism and with geothermal mechanism. As it's evident from figure above the rate of heat transfer is higher with geothermal mechanism with magnitude of 2.38 Joules and lower for design without geothermal mechanism with magnitude of 1.07 Joules.

VI. CONCLUSION

The CFD analysis of solar chimney is conducted using ANSYS CFX for 60^0 chimney inclinations initially without using perforated plates and with perforated plates. The average room temperature and air flow rate along with radiation intensity is examined.

1) For cooling application geothermal mechanism combined with inclined solar chimney has produced significant effect.
2) The room temperature reduced to about 4.5 degrees with the use of geothermal mechanism.
3) The heat transfer rate using geothermal mechanism is 2.38 joules which is higher than design without geothermal mechanism having magnitude of 1.07 joules.

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