Thermal Analysis and Design Optimization of Solar Chimney using CFD

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Abstract – *The solar chimneys can be used for power generation. In the current research the solar chimney is analyzed using CFD technique and RNG k –epsilon turbulence model. The CFD simulation is conducted under steady state conditions and 800W heat flux conditions. The temperature distribution, velocity distribution plots are obtained from the analysis.*

***Key Words*:** Solar Chimney, CFD

1.INTRODUCTION

A solar chimney, also known as a thermal chimney or a solar tower, is a type of renewable energy technology used to generate electricity from the sun's heat. It consists of a tall cylindrical structure that has a large greenhouse-like collector area at the base and a vertical chimney at the top.

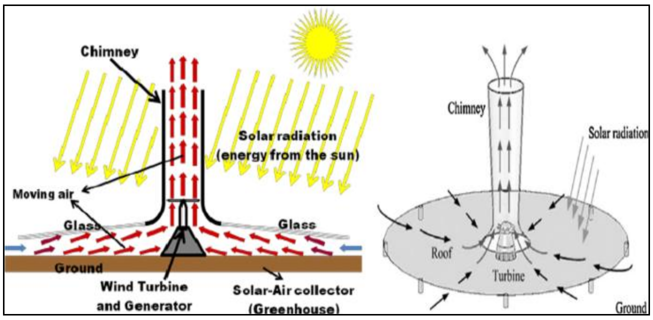

Figure 1: Solar chimney power plant [6]

The collector area is made up of a dark, heat-absorbing material that heats up the air inside it. As the air gets hot, it rises up the chimney, driving a turbine that generates electricity. The height of the chimney creates a pressure differential that helps to draw the air through the collector area and up the chimney. Solar chimneys are typically designed to operate in areas with high levels of direct sunlight and low humidity. They can generate electricity even when the sun isn't shining, as the heat absorbed by the collector area can be stored in the surrounding material and released gradually over time. While solar chimneys have the potential to generate significant amounts of electricity, they are relatively expensive to build and require a large amount of land. As a result, they are not as common as other types of renewable energy technology such as solar panels or wind turbines.

2. LITERATURE REVIEW

Kalidasa et. al. [1] This article provides an overview of the history, design, performance, and potential applications of solar chimney technology.

Khosravi et. al. [2] This article reviews the current state of solar chimney technology, including its advantages, disadvantages, and potential future developments.

Ettouney et. al. [3] This article provides an in-depth review of the technical and economic aspects of solar chimney technology, including design considerations, performance analysis, and cost estimates.

Ghasemi et. al. [4] This article reviews the current state of solar chimney technology, including recent developments, challenges, and potential future applications.

3. OBJECTIVES

The objective of current research is to investigate the thermal and fluid flow characteristics of solar chimney using RNG k-epsilon turbulence model. The fluid flow, thermal characteristics and pressure distribution characteristics are evaluated using techniques of Computational Fluid Dynamics (CFD).

4. METHODOLOGY

CFD analysis involves several steps, including geometry modeling, mesh generation, defining boundary conditions, selecting numerical methods and algorithms, solving equations, and post-processing the results. The accuracy of the results depends on several factors, including the quality of the model geometry, the mesh quality, the accuracy of the boundary conditions, and the selection of appropriate numerical methods. The CFD is based on navier's stokes equations which are derived from the principles of conservation of mass, momentum and energy. They describe how the velocity, pressure, and density of a fluid change over time in response to external forces and internal friction.

$$\partial\rho/\partial t + \nabla \cdot (\rho v) = 0 \quad \rho(\partial v/\partial t + v \cdot \nabla v) = -\nabla p + \mu\nabla^2 v + f$$

where ρ is the density of the fluid, v is the velocity vector, p is the pressure, μ is the dynamic viscosity, and f is any external body force acting on the fluid. The design of chimney is imported in parasolid file format as shown in figure 2.

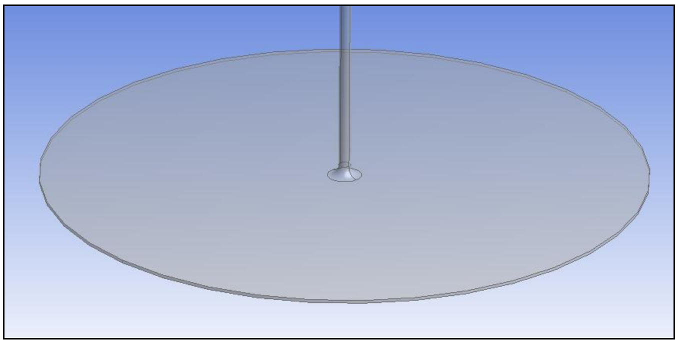

Figure 2: Imported design of solar chimney

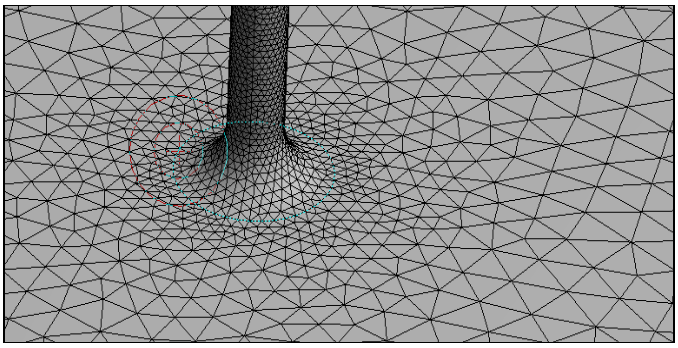

Figure 3: Meshed model of solar chimney

The imported design of chimney is discretized using tetrahedral element type with curvature effects and normal relevance. The discretized model of solar chimney is shown in figure 3.

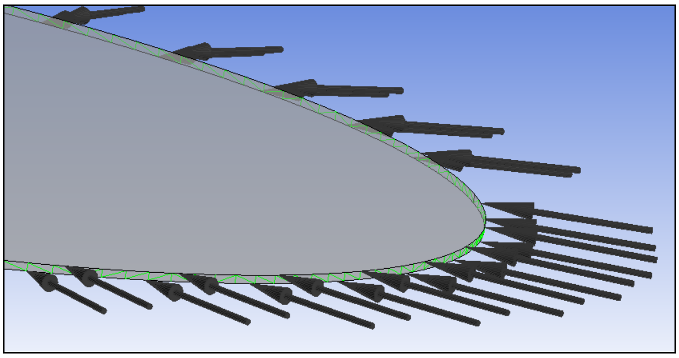

Figure 5: Meshed model of solar chimney

The inlet and outlet boundary conditions are defined as per literature [5]. These boundary conditions are shown in figure 5 and figure 6.

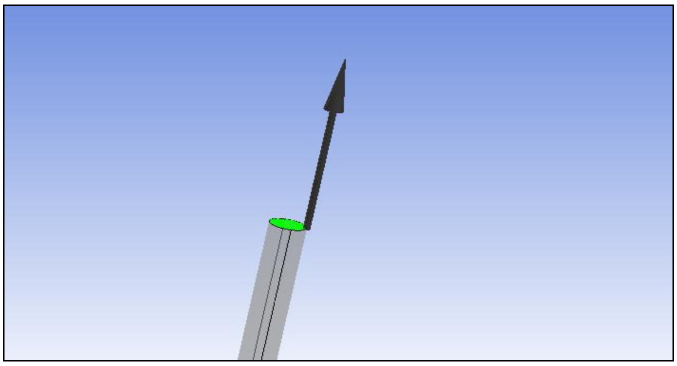

Figure 6: Meshed model of solar chimney

After applying thermal boundary conditions, the RMS residual values are defined as .0001 and advection scheme set to high resolution with 1st order turbulence numeric.

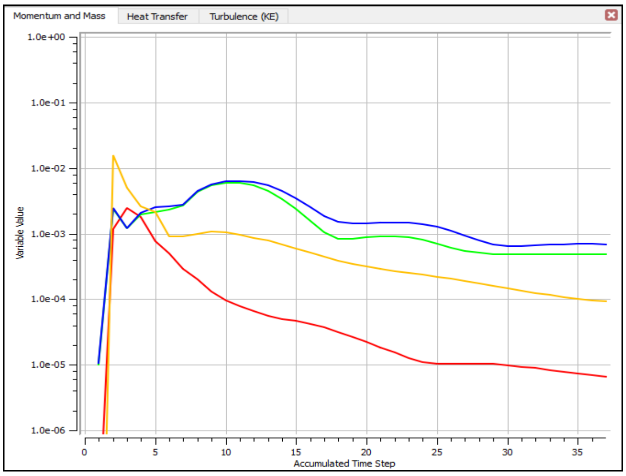

Figure 7: Convergence chart

The convergence chart showing RMS residual values are obtained for mass, momentum and kinetic energy as shown in figure 7 above.

5. RESULTS AND DISCUSSION

The CFD simulation is run to determine fluid flow distribution characteristics i.e. pressure, velocity. The pressure distribution plot is shown in figure 8. The pressure distribution plot shows uniform pressure of 4.29Pa. The pressure reduces along the height of chimney with magnitude of 1.39Pa.

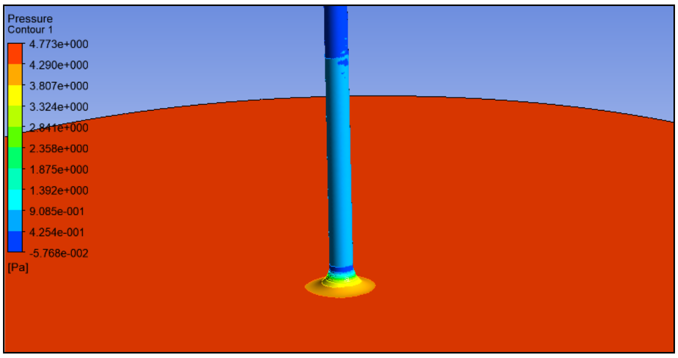

Figure 8: Pressure distribution plot of chimney

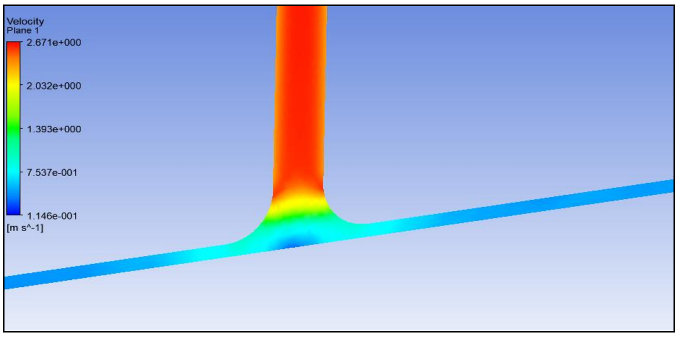

Figure 9: Velocity distribution plot of chimney

The velocity distribution plot is obtained across chimney for RNG k epsilon turbulence model as shown in figure 9 above. The plot shows higher magnitude along the exit of the chimney and lower magnitude at the throat region.

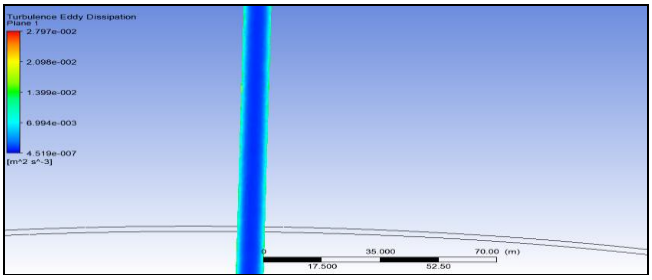

Figure 10: Velocity distribution plot of chimney

The turbulence eddy dissipation chart is generated across the plane. The turbulence eddy dissipation is found to be maximum along the edges of the chimney exit and is minimum at the center of the chimney.

6. CONCLUSION

From the CFD simulation conducted on solar chimney, the high pressure regions are obtained. The collector region exhibited high and uniform pressure. Significant pressure variation is observed only at the throat region of chimney and reduces along the vertical height. The RNG k-epsilon turbulence model provided reasonably good fluid flow predictions for air flow. The air flow magnitude varies across the throat region and becomes uniform thereafter.

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