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Design and Analysis of Solar Chimney for Passive Ventilation system

Santosh P. Basare[1], Arun M. Kulkarni[2], Rajashekhar Sardagi[3], Amol S. Dayma[4]

[1]Santosh P. Basare, Dept. of Mechanical Engineering, SSJCET Asangaon.
[2] Arun M. Kulkarni, Dept. of Mechanical Engineering, SSJCET Asangaon.
[3]Rajashekhar Sardagi, Dept. of Mechanical Engineering, SSJCET Asangaon.
[4]Amol S. Dayma, Dept. of Mechanical Engineering, SSJCET Asangaon.

Abstract - *By using solar chimney we can produce the sufficient amount of Ventilation in rooms or in a factory. In this project CFD technology is used to investigate the changes in flow kinetic energy caused by the variation of tower flow area with height. It was found that the tower area change affects the efficiency and mass flow rate through the plant. So By changing collector area, chimney tower radius and height it can possible to get maximum efficiency with small change in design of solar chimney.*

Key Words: Solar chimney, CFD analysis, Ventilation.

1. Introduction

A solar chimney is a solar power generating facility, which uses solar radiation to increase the internal energy of air flowing through the system, thereby converting solar energy into kinetic energy. The kinetic energy from the air is then transformed in electricity by use of a suitable turbine. The stack pressure difference generated can also be used for natural ventilation. The pressure difference which in turn drives the air inside the chimney is used for providing natural ventilation for a building.[30]

A solar chimney consists of three main components:

(1) The solar collector or the greenhouse

(2) The chimney, and

(3) The turbine.

1.1 Working Principle

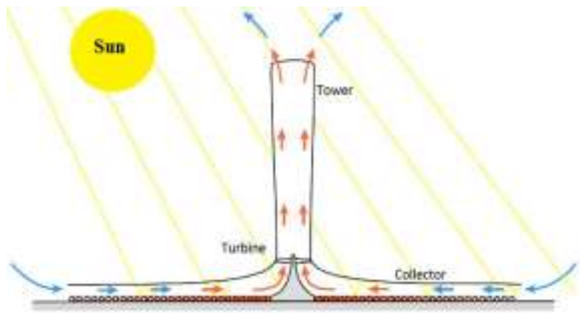


Fig. 1.1 Solar Chimney [28]

Hot air is produced by the sun under a large glass roof. Direct and diffuse solar radiation strikes the glass roof, where specific fractions of the energy are reflected, absorbed and transmitted. Through the mechanism of natural convection, the warm ground surface heats the adjacent air, causing it to rise. The buoyant air rises up into the chimney of the plant, thereby drawing in more air at the collector perimeter and thus initiating forced convection which heats the collector air more rapidly. Through mixed convection, the warm collector air heats the underside of the collector roof. As the air flows from the collector perimeter towards the chimney its temperature increases while the velocity of the air stays approximately constant because of the increasing collector height. The heated air travels up the chimney, where it cools through the chimney walls. The chimney converts heat into kinetic energy. The pressure difference between the chimney base and ambient pressure at the outlet can be estimated from the density difference.

2. Problem statement

it is necessary to develop the present renewable sources so that we can satisfy the demand. By using solar chimney we can produce the sufficient amount of Ventilation in rooms or in a factory. In this project CFD technology is used to investigate the changes in flow kinetic energy caused by the variation of tower flow area with height. So By changing collector area, chimney tower radius and height it can possible to get maximum efficiency with small change in design of solar chimney.

Objectives:

1. To Design solar chimney by using CFD.
2. To Analyse solar chimney for mass flow rate.
3. To Analyse solar chimney for Passive ventilation system.
4. To Optimize Solar chimney to increase its efficiency.

3. Introduction to CFD

Fluid dynamics deals with the dynamic behavior of fluids and its mathematical interpretation is called as Computational Fluid Dynamics. Fluid dynamics is governed by sets of partial differential equations, which in most cases are difficult or rather impossible to obtain analytical solution. CFD is a computational technology that enables the study of dynamics of things that flow. CFD provides a qualitative (and sometimes even quantitative) prediction of fluid flows by means of Mathematical modeling (partial differential equations) Numerical methods (discretization and solution techniques) Software tools (solvers, pre- and post-processing utilities) CFD enables scientists and engineers to perform 'numerical experiments' (i.e. Computer simulations) in a 'virtual flow laboratory' real experiment CFD simulation.

4. CFD Analysis of Solar Chimney

4.1 Geometric Model Creation

Geometries can be created using the pre-processor software (Ansys-design modeler). XY plane is selected in design modeler. By using sketching option 2D sketch is drawn and it is divided into 4 parts for meshing purpose. Geometry is freezed & it is converted into 3D by Revolve option. as shown in Fig

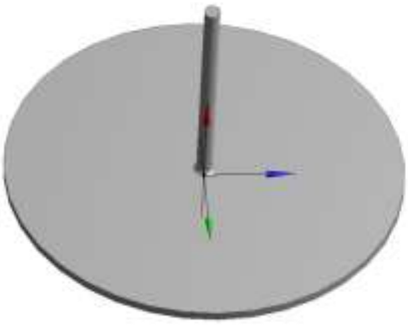


Fig. 4.1 CFD Model of Solar chimney

4.2 Mesh generation

No of elements is used for all the models 9 thousands. For the mesh generation special care has been taken to the zones close to the walls. In the proximity of the crest the mesh is finer than any other part of the domain. The domain has been subdivided into growing boxes to make it easier to generate the grid. The choice for the elements has been both Prism and hexahedral mesh volumes.

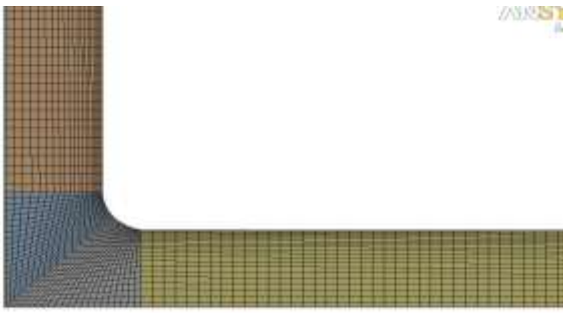


Fig. 4.2 Close View of solar chimney mesh

4.3 Boundary conditions

At the chimney inlet, the total heat flux on top wall is specified (800 N/mm^2). For mass & momentum no slip wall is selected. Smooth wall is selected as wall roughness whereas at the tower exit the 'outlet' condition with zero static pressure is prescribed. The symmetry boundary conditions are applied at the two sides of the sector while the adiabatic free-slip conditions are prescribed to the remaining boundaries, consistent with the frictionless flow assumption. All test cases were computed until residuals of all equations reached their respective minima. Moreover, global conservation of mass was rechecked to further ascertain convergence of the test cases. Inlet pressure 1000 Pa and inlet temp. 300K is selected. Ideal gas/air is selected as Flow material and Aluminum material is selected as Chimney material.

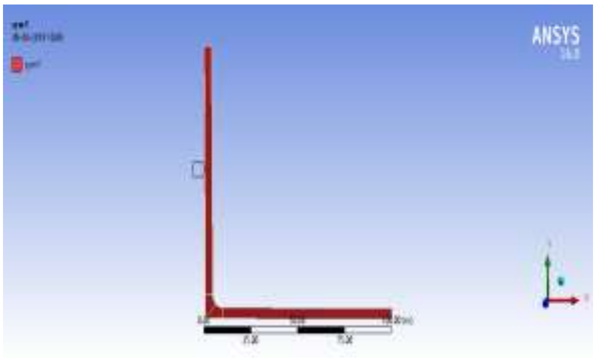


Fig. 4.3 Boundary zone symmetry 1

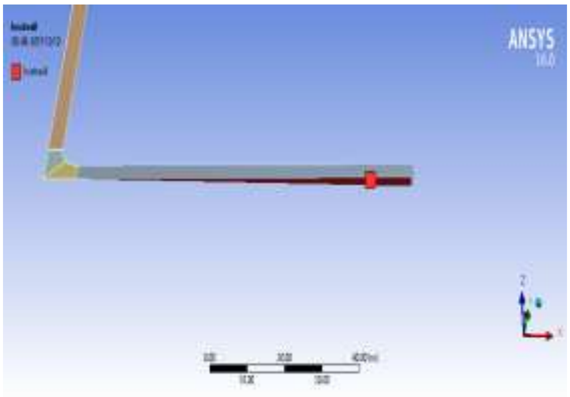


Fig.4.4 Boundary zone Heat wall

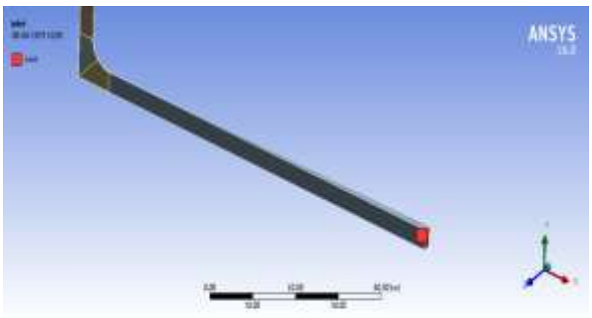


Fig.4.5 Boundary zone inlet

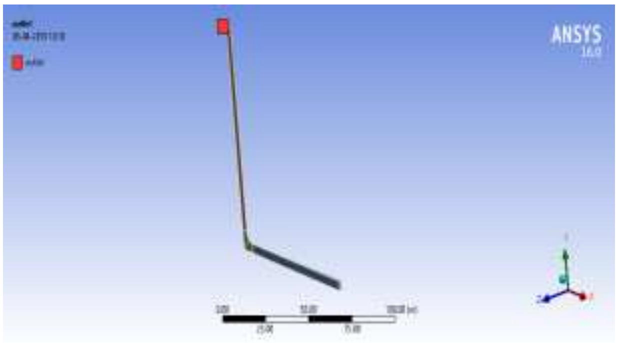


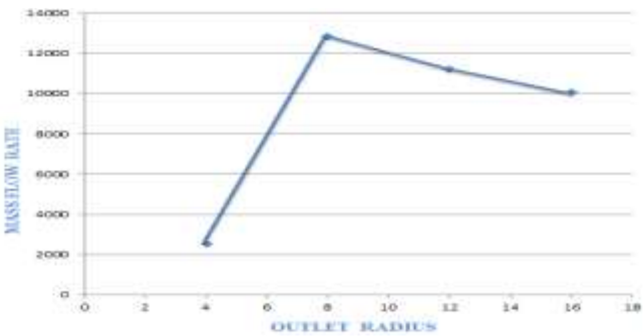
Fig.4.6 Boundary zone Outlet

4.4 Observation table

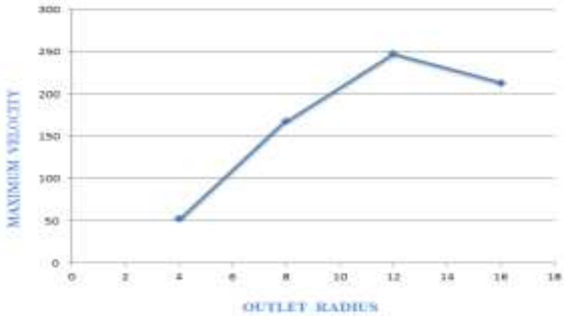
H	R_o	V_{max} m/s	$Q=A_i.V_{max}$ m^3/sec	ρ=P/gH	m=Q. ρ
125	16	213	10707	0.94	10065
125	12	247	12462	0.90	11215
125	8	168	8455	1.52	**12852**
125	4	52	2649	0.96	2543
100	16	175	8832	0.98	8655
100	12	242	12195	0.94	**11463**
100	8	175	8817	1.17	10316
100	4	52	2642	0.89	2351

4.5 Results and Discusion

A. For height of 125m and inlet radius 4m

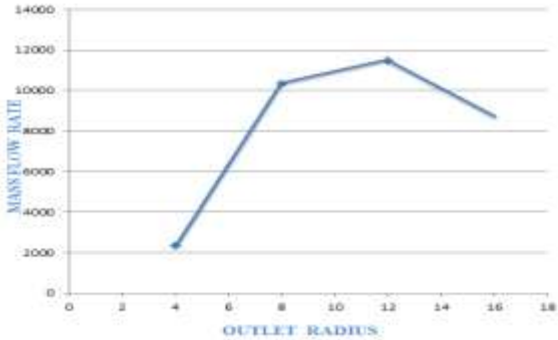


Graph .4.1 Outlet radius R_o Vs mass flow rate

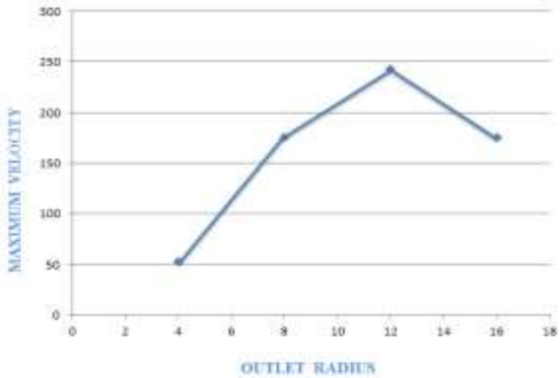


Graph .4.2 Outlet Radius R_o Vs maximum velocity V_{max}

B. For height of 100m and inlet radius 4m



Graph 4.3 Outlet radius R_o Vs mass flow rate



Graph 4.4 Outlet Radius R_o Vs maximum velocity V_{max}

5. Conclusions

a. We can design solar chimney according to requirement as follows.
For maximum Velocity, Height = 125m, Outlet Radius = 12m, Inlet Radius = 4m
For maximum Discharge, Height = 125m, Outlet Radius = 12m, Inlet Radius = 4m
For max. Mass flow rate, Height = 125m, Outlet Radius = 8m, Inlet Radius = 4m

b. From the analysis we conclude that maximum mass flow rate can be achieved by using solar chimney of Height = 125m, Outlet Radius = 8m, Inlet Radius = 4m.

c. Maximum Mass flow rate can be achieved hence solar chimney can use solar chimney for passive Ventilation system.
d. By using CFD Analysis we can identify the extra portion of height so that we can optimize it. Hence we can reduce height of chimney and can reduce cost of chimney.

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