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Thermal Analysis of Modified Solar Chimney Used For Space Ventilation in Building

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Abstract

Natural ventilation not only helps to overcome problems such as noises, maintenance and high energy consumption but can be used for green buildings for providing healthier and comfortable environment. Natural ventilation helps to save energy and give comfort to room. A solar chimney Use solar radiation to heat air inside the chimney and convert thermal energy into kinetic energy. In this project we have taken some parameters such as chimney width, height and solar intensity which show some effect in building space. In this project the CFD analysis to determine the pressure drop, velocity, heat transfer coefficient, turbulent intensity, mass flow rate and heat transfer rate for different height of chimney(0.95,0.9 &0.8m) at different solar intensity (300,500 &700 w/m2).

1. INTRODUCTION

A solar chimney is also known as thermal chimney And used to improve the natural ventilation by principle of convection, which heats the air with help of solar energy.

The solar chimney has been in use for centuries, particularly in the Middle east and Near East by the Persians, as well as in Europe by the Romans.

Solar chimney consists of black painted chimney. During day time sun rays heats the chimney and the air within it, and air rushes in the chimney. The suction is created in the chimneys base, and this is used to aerate and cool the buildings. In many countries it is easier to generate wind power for such ventilation with wind, but in still wind day solar chimney can provide ventilation.

Solar chimneys are painted with black to absorb sun's rays to heat more. And heats the inner parts of the chimney Heated air rises up and pulls cold air out from the underground with the help of heat exchange tube.

Natural ventilation process can be accelerated by solar chimney. Solar chimney height should be higher than the roof height. And should face in the direction of solar rays glazing should be done in the front direction to absorb more rays. And opposite to glazing heat absorbing material should be installed so large amount of heat can be absorbed. Heating of air within the chimney leads to convention inside the chimney and air flow inside it. Opening of vents should be kept away from the incoming winds. Solar chimney can be improved for heating in cold season by usage of Trombe wall. The advantage of Troumbe wall is providing heat during winter.

2. LITERATURE REVIEW

M R TABESHPOUR (2016)[1] ,"non linear dynamic analysis of chimney," in this paper he at last said that a modified model corresponding to dynamic characteristics of whole structure was developed to investigate seismic performance and failure of these important structure subjected to strong ground motion.

[2]M SHIVAJI and VSN RAJU (2017),"Dynamic analysis of RCC chimney," This discuses dynamic analysis of 220 m high RCC chimney for vibration

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analysis. Analysis has been done taken out for fixed base and base soil profile. And said that seismic response of tall chimney is influenced greatly by soil supporting its base and nature of earthquake hitting the base.

[3]ANURAG JAIN BEHANAM ARYA CHARLES GODDARD, "non linear dynamic analysis of industrial chimney, "In this study main problem i.e. earthquake nature of the structures, behavior of material and parts properties are seen .The importance of this study is mainly concentrated on model simplification that provides sufficient accuracy based on a nonlinear discrete model. The power plant chimney is investigated numerically as an example. The nonlinear dynamic analysis particularly needed for seismic evaluation of actual performance of complicated structures during earthquakes than the damage indices of structure had to be calculated using appropriate damage models.

[4]NEGAR SADEGH POUR, INDRAJEET CHOUDHARY (2008),"dynamic soil structure analysis of tall multi flue chimney under aerodynamic and seismic forces, "The present paper proposes a semi analytic mathematical model based on which both seismic and aerodynamic response of such a tall chimneys are studied for various soil stiffness and are compared with fixed base conventional method as per UBC 97(for seismic load) and CICIND (for wind loading). Soil Structure also has an important effect on seismic forces of tall chimneys. Though tall chimney rests on firm soil, earthquake loads reduced as a result of increasing in period values.

This studies give a novelty to use CFD for study of solar chimney in space heating. [5]The modified solar chimney is useful technique and can be used in building space ventilation. We can decrease the amount of energy used in space heating and ventilation system up to some extent in residential and commercial buildings .The more research is needed to be taken by research tool and develop prototype and standardizing the solar chimney.

Table 1. Nomenclature

C	constant	T	Temperature
Cp	Specific heat	t	Turbulence
Fp	Buoyancy force.	U	Velocity
g	Gravitational constant.	α	Absorbity
h	Enthalpy	β	Coefficient of thermal expansion
k.	Kinetic energy	ε	Energy dissipation
kef	Effective conductivity	μ	Dynamic viscosity
kf	Fluid thermal conductivity		Turbulent viscosity
kt	Turbulent thermal conductivity	ρ	Density of air
p	Pressure	ρ0	Reference density
prt	Turbulent Prandtl number.		
Sh	Source term with solar		

CFD simulation strategy

We consider the steady turbulent flow model, so that Reynolds-Averaged Navier-Stokes equationsTable 2.Dimensions of modeled solar chimney(RANS) are used for modeling with (k − ε) model. The Bousinesque approximation is used to account forair density variation in buoyancy flow. The dimensions of modeled solar chimney are shown in Tab. 2.

S.No. Specifications	Dimensions (m)
1. Absorber plate area	2.50
2 .Thickness of absorber plate (MS plate)	0.003
3. Air gap between glazing and absorber plate	0.06
4. Chimney height	0.95
5. Dimension of inlet vent	0.30 × 0.30
6. Dimension of outlet vent	0.30

The assumption for the study of flow and heat transfer distribution in collector are given as steady state symmetric , collector, ground model .All the calculations were determined with the k –ε model and the basic equation summarize as below.

Basic equation

The realizable k-epsilon turbulent model with discrete ordinance model for CFD simulation model has been used. The time averaged Navier Stokes (TANS) equation for the mass and momentum transport are given by

Continuity equation:

$$\frac{\partial u_i}{\partial x_i} = 0 \quad (1)$$

The momentum conservation equation :

$$\rho(u_j \frac{\partial u_i}{\partial x_j}) = \frac{p}{\partial x_j} + \frac{\partial}{\partial x_j}[(\mu + \mu_t) \frac{\partial u_i}{\partial x_j} + f_b \quad (2)$$

Buoyancy force = $f_b = (\rho - \sigma_0) g$ (3)

Energy conservation is given is

$$\rho U_i \frac{h}{\partial x_i} = k_{eff} \frac{\partial}{\partial x_i}\left[\frac{T}{\partial x_i}\right] + S_h \quad (4)$$

Effective conductivity is

$$k_{eff} = k_f + k_t \quad (5)$$

Turbulent conductivity

$$k_t = \frac{C_p \mu_t}{p_{rt}} \quad (6)$$

Turbulent model

$$\rho U_j \frac{\partial k}{\partial x_j} = \tau_{ij} - \rho \varepsilon + \frac{\partial}{\partial x_j}[(\mu + \frac{\mu_t}{\sigma_k}) \frac{\partial k}{\partial x_j}]$$
(7)

Final Radiative Transfer Equation is given by coupling with a volumetric source is

$$S_h = -\frac{\partial q_{ri}}{\partial x_i} = \alpha_\lambda [4\pi I_{b\lambda}(\vec{x}) - \int_0^{4\pi} I(\vec{r}, \vec{s}) d\Omega$$
(8)

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Boundary conditions

A static pressure boundary conditions is used at chimney exit (p out (x) =0).It means pressure at inlet and outlet of solar chimney is equal to atmospheric pressure. And the simulated inlet temperature of solar chimney is equal to the room temperature at the same time which observed in the experiments Table3. properties of material

Input parameters

A 2 -D steady, Realizable k – epsilon turbulent model with standard wall function is used for the study. Some of the important properties of material and modeling parameters are required for the CFD simulation which is shown in Tab. 3 and tab. 4. Shown below

Material	ρ, kg/m3	Cp, j/kg C	k, W/m C	Emissivity	Absorptivity	Transmitivity
Mild steel	7800	500	52	0.95	0 .95	0
Glass	2500	820	01	0.9	0.06	0.84
Air	1.225	1006.43	0.0242			

Table 4. Molecular weight and viscosity of air

Description	Unit	Particular/values
Viscosity	Kg/m – s	1.7894 × 10−5
Molecular weight	Kg/kg.mol.	28.966

3. CFD SIMULATION MODELLING AND MESHING

Computational fluid dynamics Shortened as CFD. It is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problem that is related to fluid flows. Computers are used to do the calculation which is needed to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. High-speed super computers, can help to get better solutions.

CFD is working on step by step method

Geometry: based on dimensions described in Tab. 2 is designed. After that grid is generated through meshing software. The quality of grid mesh play direct role on quality of the analysis. Meshing is the key for convergence and accurate CFD solutions.

CFD ANALYSIS OF SOLAR CHIMNEY

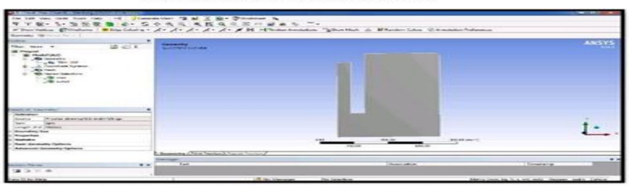

Fig.1. Imported model

Mesh adoption: It used to refine the mesh based on geometrical and flows to be better resolved. Parameters controlling the mesh adoption is set in the control dialog box, and right mark on refine and coarse option and select the both fluid stator and fluid rotors. It can be improved by smoothing and numerical solutions. Cells are in mesh this allows the features of the fluid swapping control .mesh adaption with height 0.95 m and width 0.2m at solar intensity

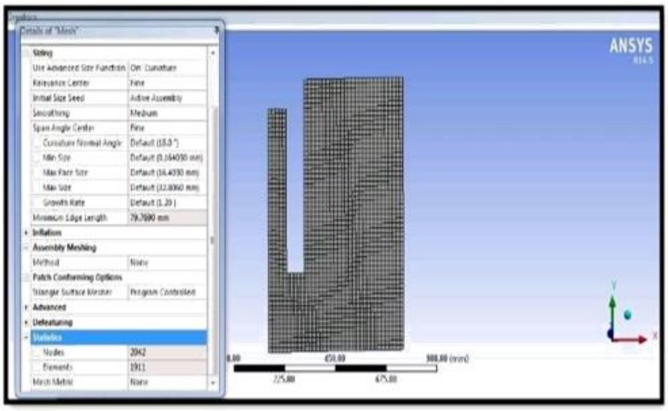

Fig . 2 solar chimney air flow with mesh adaption

Case1: Solar chimney height: 0.95m

Solar intensity 300w/m^2

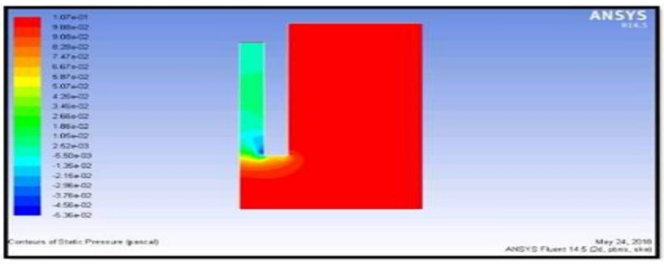

Fig 3 .pressure

4. Result and Discussion

Result obtained for different height of chimney and solar intensity is

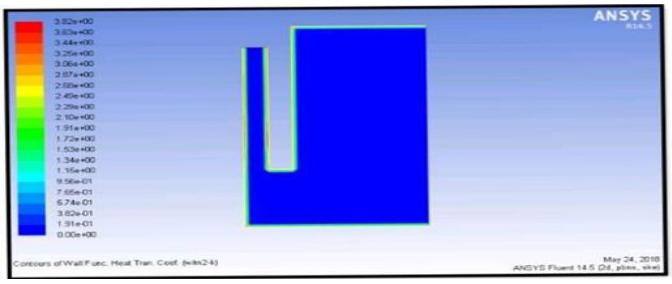

Fig. 4 velocity

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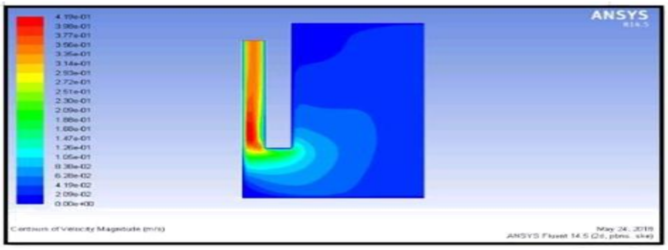

Fig .5 heat transfer coefficient

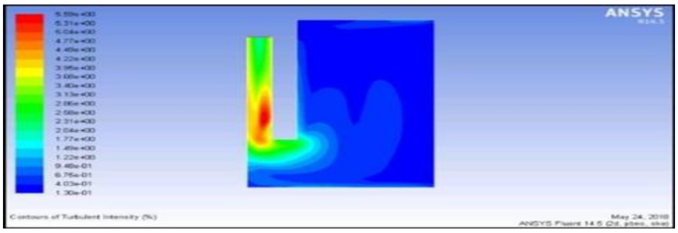

Fig 6. Turbulent intensity

Cfd Result Table 7

CFD RESULT TABLE

Model (chimney height(m))	Solar intensity (w/m2)	Pressure (Pa)	Velocity (m/s)	Heat transfer coefficient (w/m2-k)	Turbulence intensity (%)	Mass flow rate(kg/s)	Heat transfer rate(W)
0.95	300	1.07e-01	4.19e-01	3.82	5.59	0.000052616	5.7156
	500	1.33e-01	4.66e-01	4.18	6.28	0.00010842	9.7089
	700	1.49e-01	4.98e01	4.40	6.69	0.0000759	21.976
0.9	300	9.67e-02	3.97e-01	3.69	4.84	0.000057489	2.0258
	500	1.23e-01	4.38e-01	3.94	5.53	0.00013865	37.717
	700	1.24e-01	4.68e-01	4.12	6.02	0.0001105	37.216
0.8	300	8.44e-02	3.74e-01	3.8	5.32	0.00002878	22.7253
	500	9.42e-02	4.19e-01	4.15	5.91	0.00017393	25.34436
	700	1.07e-01	4.46e-01	4.38	6.33	0.00012237	14.20047

GRAPHS

CFD simulated results at different height of chimney with different solar intensity shows some effect in thermal properties of the system

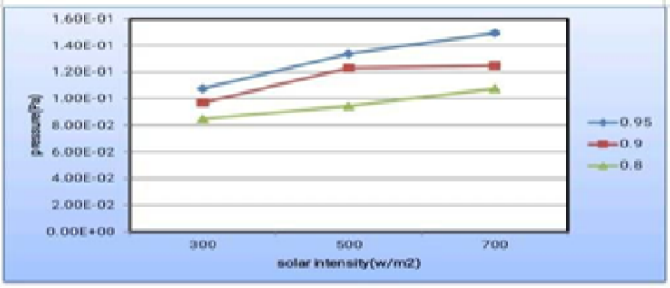

Fig.7. Pressure Vs Velocity

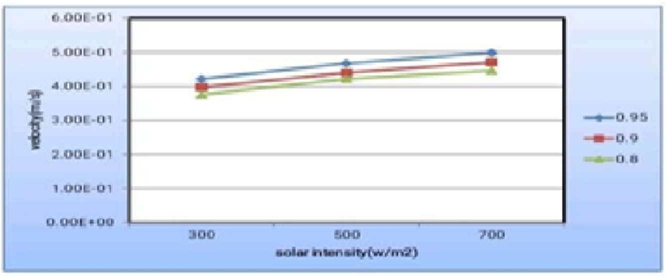

Fig.8. Velocity Vs Solar Intensity

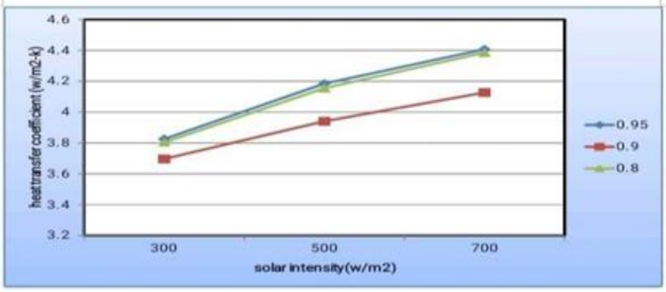

Fig.9 Heat Transfer Coefficient Vs Solar Intensity

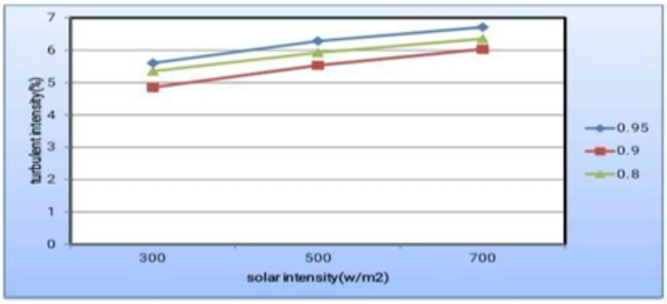

Fig.10 Turbulent Intensity Vs Mass Flow Rate

Simulated results has been shown below

5. Conclusion

Natural ventilation system is source to solar chimney system is developing natural improve thermal comfort and save energy .A draft device, which heats the inside air of

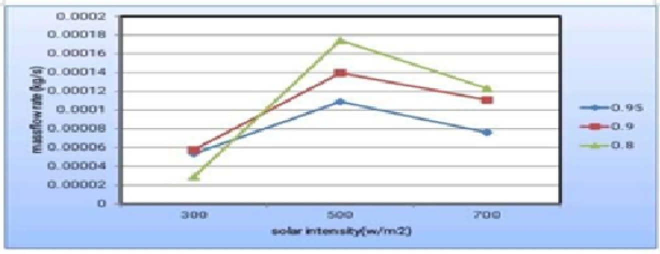

Fig .11 Mass Flow Rate Vs Solar Intensity

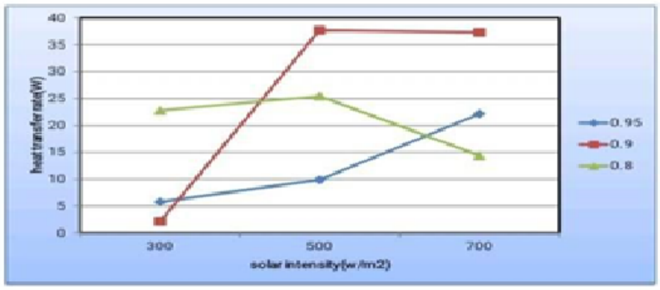

Fig.12. Heat Transfer Rate Vs Solar Intensity

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In this thesis the CFD analysis is used to determine the pressure drop, velocity, heat transfer coefficient, turbulent intensity, mass flow rate and heat transfer rate for different height of chimney(0.95,0.9 &0.8m) at different solar intensity (300,500 &700 w/m2).

By observing the CFD analysis results the pressure, velocity, heat transfer coefficient, turbulent intensity values are increases by increasing the solar intensity. The heat transfer coefficient values are more for solar chimney height 0.95m.This studies can be used for different absorber plate and glass materials with different width and height of solar chimney to increase thermal performance. Solar chimney .And convert thermal energy into kinetic energy.

REFERENCES

[1]M R Tabeshpour, "Nonlinear Dynamic Analysis of Chimney-like towers", Asian Journal of Civil Dynamic Analysis of RCC Chimney- A Review (IJSRD/Vol. 4/Issue 02/2016/037) All rights reserved by www.ijsrd.com 120 Engineering (Building and Housing), vol.13, NO.1 (2012), pp.97-112.

[2]Victor bochicchio, “Design of chimney with GRP liner for low and high temperature operation”, Vol-22, no-1, pp-1-5.

[3]M Shivaji and V S N Raju, "Dynamic analysis of RCC Chimneys ", pp.1-14.

[4]Anurag Jain, Behnamarya, Charles Goddard and Jon Galsworthy, "Non linear Dynamic Analysis of an Industrial Chimney's Pile foundation system for hurricane loading", 11th Americas conference on windengineering -sanguine, Pucrtorico, June-22-26, 2019.

[5]K.S.BabuNarayan, Subhas .C. Yaragal, and Yukio Tamura, “Interaction Envelops for Limit State Design Chimneys”, The fourth International Symposium on computational Wind Engineering (cwe2006), Yokohama, 2006, pp 439-442.