SIMULATION OF ROOF SOLAR CHIMNEY FOR VERTICAL AXIS WIND TURBINE

FARZAD RAMESH ZARCHI

A project report submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Mechanical)

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

JANUARY 2013

ACKNOWLEDGEMENT

First of all, I would like to express my utmost gratitude towards Prof. Dr. Farid Nasir Bin Hj Ani, the supervisor for his guidance and advice towards the completion of this project. He has shared me his knowledge which has been a great strength for me to face the challenges throughout the completion of the project.

Last but not least, I have to thank my beloved friends for lending me their hands in making my project a fruitful one.

ABSTRACT

Due to the important role of the renewable and sustainable energy sources in energy sector, a lot of efforts are made to reduce fossil fuel consumption. One option in small scale energy generation is roof solar chimney. Among many factors that affect the performance of a roof solar chimney is the angle of sun radiation which is an important factor that varies with different locations. It is crucial to find the optimum angle that a solar absorber should face the sun beams to absorb as much as solar energy as possible and get to its highest temperature possible. A location between 35^o to 45^o latitude is selected to simulate its climatic condition. The results show that an inclination of 30^o from horizon seems to be a perfect choice for solar absorbers. An increase in geometry is necessary to get the required velocity output of the outlet opening of the solar chimney to power up a vertical axis wind turbine (VAWT). At least 3m/s of wind speed is required for the wind turbine (VAWT) with the rotor diameter of 1 meter. Final radius of the solar chimney to satisfy the need was about 4 meters.

ABSTRAK

Oleh kerana pentingnya peranan sumber tenaga boleh diperbaharui dan mapan dalam sektor tenaga, banyak usaha telah dibuat untuk mengurangkan penggunaan bahan api fosil. Salah satu pilihan dalam penjanaan tenaga berskala kecil adalah cerobong bumbung suria. Antara banyak faktor yang mempengaruhi prestasi cerobong bumbung suria adalah sudut sinaran matahari dimana ia adalah faktor penting yang berbeza dengan lokasi yang berbeza. Ini adalah penting untuk mencari sudut optimum bagi penyerap suria yang harus menghadapi rasuk matahari untuk menyerap seberapa banyak tenaga suria yang boleh dan sampai ke suhu maksimum mungkin. Satu lokasi antara 35° hingga 45° latitud dipilih untuk mensimulasikan keadaan iklim. Keputusan menunjukkan bahawa kecenderungan 30° dari ufuk seolah-olah menjadi pilihan yang sempurna untuk penyerap solar. Peningkatan dalam geometri adalah penting untuk mendapatkan halaju keluaran yang diperlukan kepada keluaran cerobong suria untuk penjanaan kuasa bagi kincir angin (VAWT). Sekurang-kurangnya 3m / s kelajuan angin diperlukan bagi kincir angin (VAWT) bergarispusat 1 meter. Jejari akhir cerobong suria untuk memenuhi keperluan kajian ini adalah kira-kira 4 meter.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

P	-	Power output
Q	-	Solar input
η	-	Efficiency
G_h	-	Global horizontal radiation
G_o	-	Irradiance falling on horizontal plane
G_d	-	Daily global irradiance
A_{coll}	-	Collector area
$\dot{m}$	-	Mass flow rate
v, U	-	Velocity
$\overline{u}$	-	Mean velocity
H	-	Height of the solar chimney
T_o	-	Ambient temperature
T_i	-	Internal temperature
ΔT	-	Average temperature gradient
g	-	Gravity acceleration
c_p	-	Specific heat
ε	-	Correction to mean solar distance
γ_s	-	Solar altitude in degrees
j’	-	Day’s angle
ω	-	Hour angle

φ	-	Latitude
δ	-	Solar declination angle
α_s	-	Azimuth angle
α_F	-	Resolved angle on the horizontal plane
S_d	-	Daily sunshine
S_{od}	-	Astronomical day length
δ_{od}	-	Daily observed sunshine
υ	-	Angle incidence on the specific surface
ρ	-	Density
μ	-	Viscosity
$\bar{\bar{\tau}}$	-	Tension stress
D	-	Diameter
D_h	-	Hydraulic diameter
β	-	Thermal expansion coefficient
L	-	Length of the plane
Ps	-	static pressure
Pr	-	Prandtl number
k	-	Thermal conductivity
δ_T	-	Thermal boundary layer thickness
K	-	Constant of resistance by opening
I	-	Solar intensity
Gr	-	Grashof number
Nu	-	Nusselt number
Re	-	Reynolds number
H	-	Heat transfer coefficient

LIST OF APPENDICES

CHAPTERT 1

INTRODUCTION

Background

The prospect of global warming and limited fossil fuel resources has made the renewable and sustainable energy becomes more important in energy sector. A variety of methods have been developed to capture the energy from natural sources such as sun, wind or geothermal energy from small scales like a house to large power plants.

Architects and building engineers are encouraged to search for ways of heating, cooling and ventilating buildings by passive means rather than energy-consuming mechanical devices. Among these is the solar chimney, essentially a solar energy absorber with open top and bottom, which induces airflow through a building when solar radiation impinges on it. A solar chimney could be inclined as is shown if Figure 1.1 or vertical as is shown in Figure 1.2. The buildings with gable roofs have the potential to be well designed to integrate with inclined solar chimneys to form roof solar chimney. A wind turbine ventilator can be coupled with the roof solar collector that use natural air and the hot air (driven by stack effect) to produce mechanical power and can be converted to electrical energy to run the household devices as seen in Figures 1.3 and 1.4.

Design of the solar chimney is therefore important both in providing efficient air movement and in preserving the architectural integrity of the building. A number of factors influence the design of the chimney: the location, climate, orientation of the building, size of building to be ventilated, and internal heat-gains. In this research a section of a conical shaped roof solar collector will be simulated to find the optimum tilt angle. The roof solar chimney will be expanded at optimum inclined angle to achieve the desired hot air velocity outlet to drive a specific wind turbine ventilator.

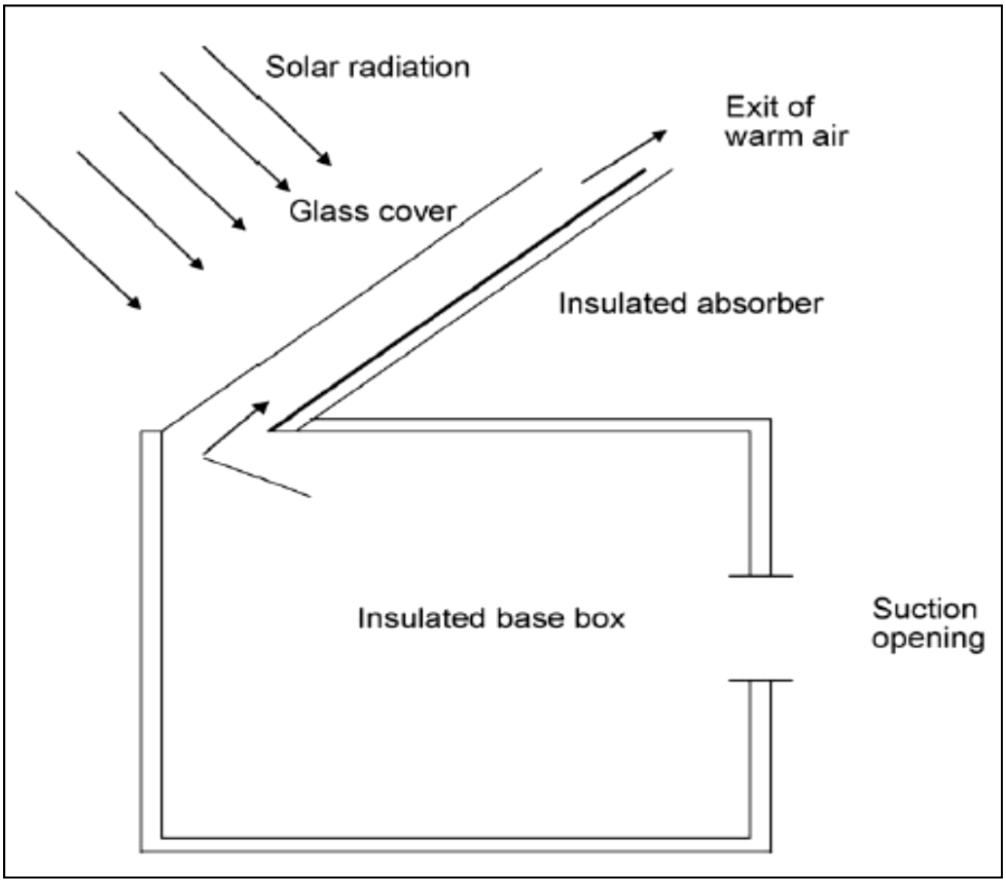

Figure 1.1 Inclined roof solar chimneys configuration (Mathur and Mathur, 2008)

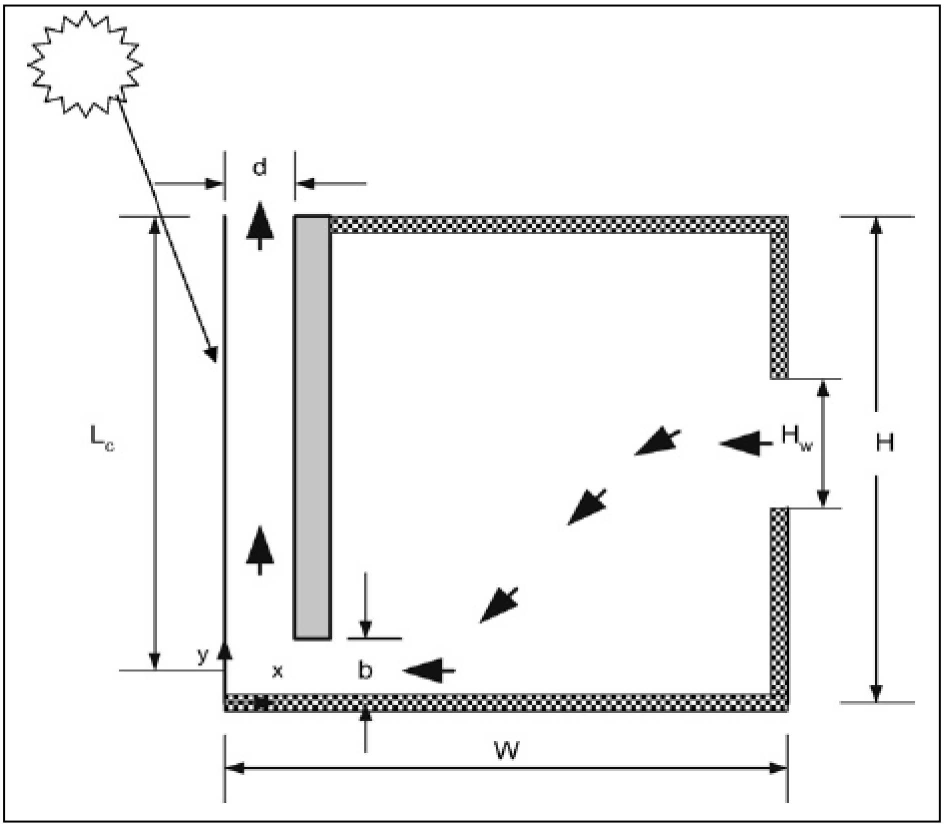

Figure 1.2 Vertical roof solar chimney (Bassiouny and Koura, 2008)

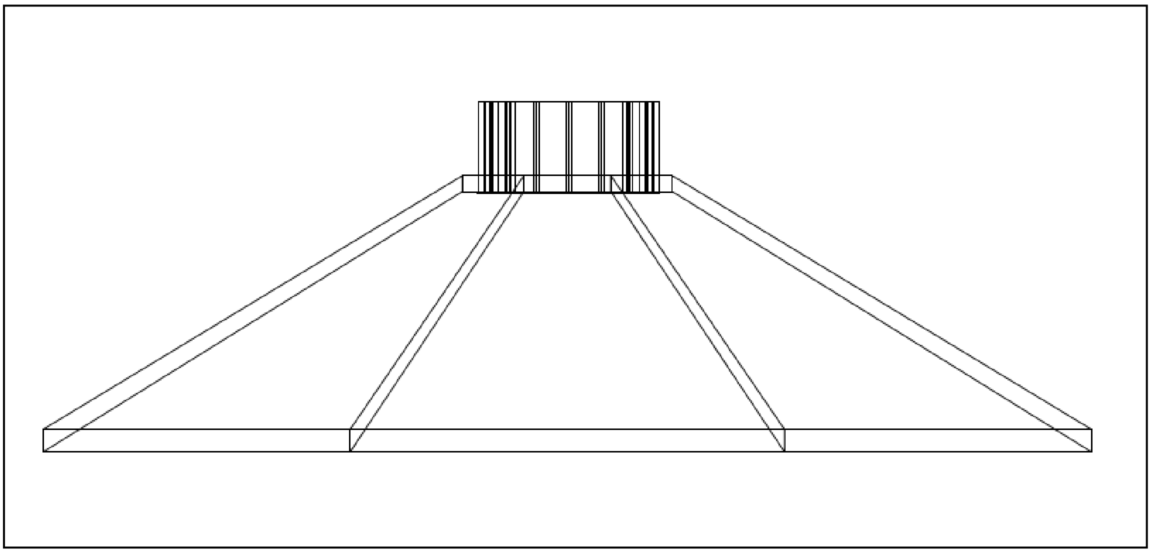

Figure 1. 3 Roof solar chimney combined with a vertical axis wind turbine ventilator.

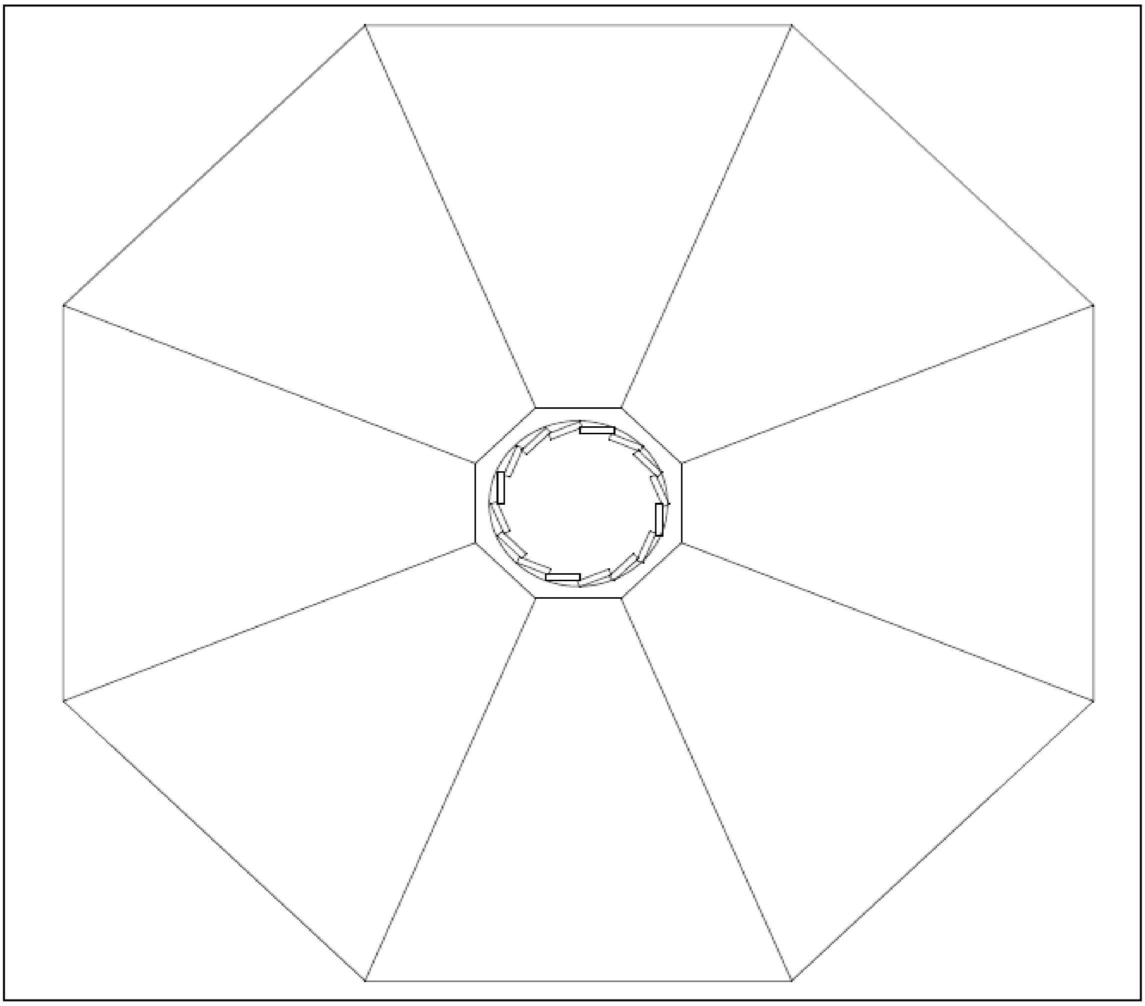

Figure 1.4 Top view of combined system of roof solar chimney and vertical axis wind turbine

OBJECTIVES

i) To determine the slope of the solar collectors based on initial prototype design.

ii) To determine the dimensions that can be able to produce required wind speed needed to power up a specific wind turbine ventilator.

SCOPE

i) Steady state condition.

ii) Data of solar and wind speed.

REFERENCES

Bahadori, A and Nwaoha, C. (2013). *A review on solar energy utilization in Australia*. renewable and sustainable energy reviews. (18):1-5.

Bansal, N and Mathur. R. (1993). Solar *chimney for enhanced stack ventilation*, Building and Environment. (16): 373–377.

Bassiouny. R and Koura. N, (2008). *An analytical and numerical study of solar chimney use for room natural ventilation*, Energy and Buildings. (40)865–873.

Bhutto, A. W, Bazmi. A. A and Zahedi. G (2012). *Greener energy :issues and challenges for Pakistan-solar energy prospective*. Renewable and Sustainable Energy Reviews 16(5):2762–2780.

EREC. European Renewable Energy Council. (2006). Renewable energy target for Europe by 2020. (Brief Paper, Brussel); (2006).

Etheridge, D and Sandberg, M. (1996). *Pressure Differences generated by Temperature.* Building Ventilation: Theory and Measurement. 28-29.

FLUENT, Inc. ANSYS FLUENT 6.3 theory guid (2004).

Goh Wee Chong (2010). *Design of hot air and wind turbine ventilator*. Universiti Teknologi Malaysia: Bachelor Degree Thesis.

Hasnain, S and Elani U.A. (1998) *Solar energy education* – a viable pathway for sustainable development. 14(1–4):387–92.

Incropera, Dewitt, Bergman and Lavine (2007). *Heat transfer*. 5th edition, John Wiley and Sons, pp A-14, 2007.

Johnson, G. L. (1985). *Wind Energy Systems*. Englewood Cliffs, N.J.:Prentice-Hall. (1985).

Lappa, M. (2010). *thermal convection patern evolution and stability*. united kingdom: john wiley & sons.

Manwell J.F., McGowan J.G. and Rogers A.L. (2009). *Wind Energy explained: Theory, Design and Application*. Second Edition. University of Massachuselts, Amherst, USA: John Wiley & Sons Ltd.

Mathews. J. A (2007). Carbon negative biofuels. JournalofEnergyPolicy. 36:940–5.

Mathur.J , Mathur. S and Anupma. (2006). *Summer-performance of inclined roof solar chimney for natural ventilation*. Energy and Buildings. 1116-1163.

Othman AK, Jakhrani AQ, Abidin WAWZ, Zen H and Baharun. A (2010). *Malaysian Government Policy*. *In: Renewable Energy*. Solar PV System, in World Engineering Congress 2010, 2nd–5th August 2010.

Rapp, D. *Solar Energy*. 1th edition University of Texas, Englewood Cliffs, N.J.:Prentice-Hall. (1981).

Sakonidou E. P, (2008). *Modeling of the optimum tilt of a solar chimney for maximum air flow*. Solar Energy. 80–94.

Scharmer. K and Greif. J (2005). The European Solar Radiation Atlas. Paris. (1).

Schlaich, J. and Schiel, W. (2001). "*Solar Chimneys*", Encyclopedia of Physical Science and Technology, 3rd Edition, Academic Press, London.

Schlaich,J, Bergermann,R., Schiel,W and Weinrebe, G. (2005). *Design of Commercial Solar Updraft Tower Systems – Utilization of Solar Induced Convective Flows for Power Generation*., Energy engineering. 127(8).

Tiwari G.N. (2006). Centre *for energy Studies. Indian Institute of technology*, Dehli, New Dehli. Alpha Science international Ltd.

Turner, Wayne C. and Steve, Doty., (2007). Energy Management Handbook.

Walker, J. F and Jenkins. N. (1997). *Wind Energy Technology*, UNESCO, England.

White, F. (2007). *Advanced fluid mechanics*. 7th edition. Mc Graw Hill.

Yusaf. T, Goh. S, Borserio. J. A (2011). *Potential of renewable energy alternatives in Australia.* Renewable and Sustainable Energy Reviews. 15:2214–2221.

Zhai. X., Song. P., Wang. Z., (2011). *A review for the applications of solar chimneys in buildings.* Renewable and Sustainable Energy Reviews. (15). 3757-3767.