INVESTIGATING THE TEMPERATURE PROFILE OF INCLINED SOLAR CHIMNEY (ISC)

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FACULTY OF ENGINEERING
UNIVERSITI MALAYSIA SABAH

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THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF BACHELOR OF MECHANICAL ENGINEERING

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DECLARATION

I hereby declare that this thesis, submitted to Universiti Malaysia Sabah as partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering, has not been submitted to any other university for any degree. I also certify that the work described herein is entirely my own, except for quotations and summaries sources of which have been duly acknowledged.

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5th June 2015 Choo Yin Pei

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ABSTRACT

This study is mainly concerned with the performance of an inclined solar chimney (ISC) when applied on the climates of Malaysia, namely in the city of Kota Kinabalu, Sabah. Generally, the objectives of this project include the design and development of an incline solar chimney for the purpose of house ventilation, the empirical relationships between the heat transfer across the solar chimney and various parameters set in this project and also the evaluation of the performance of the solar chimney model. The chimney model was tested by varying the inclination angles and the various temperature parameters of the model were recorded. Also, the design of the chimney model was improved by placing of a wire mesh across the of the chimney model. After a round of results and analysis, it was found out the optimum angle of the model that achieved the highest performance among the sets of inclination angles tested was 45° which was in accordance with the findings of past researches and the placing of wire mesh at the outlet had increased the outlet flow velocity significantly. Further improvements on the chimney model in future research include the testing of more sets on inclination angle, the increasing of the air gap of the flow channel and also the obtaining of more accurate results by taking the actual temperature at the outlet instead of just comparing with theoretical results.

ABSTRAK

Kajian ini adalah tertumpu kepada pelaksanaan sesuatu cerobong solar cenderung (ISC) apabila digunakan pada iklim Malaysia, iaitu di bandar Kota Kinabalu, Sabah. Secara umumnya, objektif projek ini termasuk reka bentuk dan pembangunan cerobong solar cenderung untuk tujuan pengudaraan rumah, hubungan empirikal antara pemindahan haba di cerobong solar dan pelbagai parameter yang ditetapkan dalam projek ini dan juga penilaian prestasi model cerobong solar. Model cerobong telah diuji dengan mengubah sudut kecondongan dan pelbagai parameter suhu model telah direkodkan. Selain itu, reka bentuk model cerobong telah dipertingkatkan dengan meletakkan sebuah jejaring dawai merentasi model cerobong. Selepas analisis telah dibuat, ia didapati bahawa sudut optimum model yang mencapai prestasi yang tertinggi di kalangan set sudut kecenderungan yang diuji adalah 45 ° dan keputusan is adalah selaras dengan dapatan kajian lepas dan meletakkan dawai di keluaran model cerobong telah meningkatkan halaju aliran keluar dengan ketara. Penambahbaikan kepada model cerobong dalam penyelidikan masa depan termasuk pengujian lebih set kepada sudut kecondongan, peningkatan jurang udara saluran aliran dan juga mendapatkan keputusan yang lebih tepat dengan mengambil suhu sebenar pada keluaran bukan hanya membandingkan dengan keputusan teori.

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LIST OF SYMBOLS

A_i, A_o	Cross-sectional area of inlet and outlet to air flow channel (m^2)
A_g	Area of glass (m^2)
A_w	Area of absorber (m^2)
C_d	Coefficient of discharge of air channel inlet
C_a	Specific heat of air (J/kg.K)
h_g	Convective heat transfer coefficient between glass glazing and air channel ($W/m^2.K$)
h_w	Convective heat transfer coefficient between absorber and air channel ($W/m^2.K$)
h_{rs}	Radiative heat transfer coefficient between glass glazing and air channel ($W/m^2.K$)
h_{rw}	Radiative heat transfer coefficient between absorber and air channel ($W/m^2.K$)
T_g	Temperature of glass cover (K)
T_w	Temperature of absorber wall (K)
T_f	Temperature of fluid (K)

U_t	Overall heat loss coefficient from top of glass glazing ($W/m^2.K$)
U_b	Overall heat loss coefficient from bottom of absorber ($W/m^2.K$)
q''	Heat transfer to air stream (W/m^2)
S_1	Solar radiation heat flux absorbed by glass glazing (W/m^2)
S_2	Solar radiation heat flux absorbed by glass absorber (W/m^2)
V_{out}	Velocity of flow channel (m/s)
γ	Constant for mean temperature approximation
P_r	Prandtl Number
μ	Dynamic Viscosity
C_P	Specific Heat
K	Thermal Conductivity
ρ	Density
Nu	Nusselt Number
$\dot{Q}$	Heat transfer rate

CHAPTER 1

INTRODUCTION

1.1 Overview

The uses of fossil fuels such as petroleum products, gases etc. to generate electricity are increased significantly in the last thirty years. At present, these energy sources are now under thread because to population increases, development of technology, human comfort etc. Therefore, scientists are trying to find out alternative source of energy for electricity generation. Among all the alternative sources of energy, solar energy has higher potential value because of its abundant all over the world (Jennings 2007).The applications of solar energy are also wide started from electricity generation, house ventilation to drying agricultural products. Generally Photovoltaic cellis used to generate electricity for ventilation and cooling but the cell efficiency and production cost is made the overall system inefficient. On the other hand, solar chimney power plant may be a suitable option to supply electricity to the house for ventilation and cooling but the installation and maintenance of solar chimney is one of the challenging tasks for engineers. Therefore a solar chimney assisted house ventilation system will be valid options for house ventilation and cooling.

The solar chimney, more commonly known as thermal chimney, is a structure that helps to exchange hot air with cold air from the building or space which is known as ventilation. Hence, the solar chimney works as a fluid pump which is driven by solar energy. In general, the solar chimney consists of three basic elements which are the solar collection area, main ventilation shaft and the inlet and outlet apertures. The solar chimney can be used in buildings effectively because of its simplicity in design as well as its eco-friendly characteristics. Figure 1.1 shows a house with solar chimney ventilation system.

The solar energy is absorbed by the solar collector which usually acts like a blackbody and transmitted heat to adjacent air and so on. The hot air is flowing through the main ventilation shaft due to stack effect which is known as natural convection flow or natural ventilation. In natural ventilation system due to the density difference between hot air and cold air, the hot air which has a lower density will start to move in the upward direction. Therefore a pressure difference is established between inlet and outlet of the solar chimney that results in continuous flow of air until the heat energy is available in the solar collector. This phenomenon is known as the stack effect (Haggard and Bainbridge. 2011).

The application of the solar chimney is not limited to create ventilation for buildings only. As technology advances, researchers have attempted to expand the uses of the solar chimney to other areas such as power generation system, solar food dryers etc. In the solar chimney power generation system the solar chimney is used as solar updraft tower that crate sufficient draft between inlet and outlet. As a result the air is started to move and run the turbine to generate electricity. The solar food dryer, the solar chimney is used to create air flow and to enhance drying rate. The foods drying rate depends on temperature, humidity and air flow rate. Although solar chimney has very good prospect but a suitable height and tilt angle of the solar chimney for effective use in Sabah Malaysia is still unknown. According to Rahman et.al (2013) the solar chimney height can be minimized by using wire mesh screen at top of the chimney but very limited research was found on tilt angle of the solar chimney therefore it is aim study the solar chimney performance under different tilt angle. This is considered as a fairly good accomplishment as solar energy is one of the most popular alternative energy sources due to its abundance. More and more researches are being carried out regarding this topic as its development will be very beneficial to the environment. Apart from that, the solar chimney can also be used as a drying system by integrating it with the solar updraft tower.

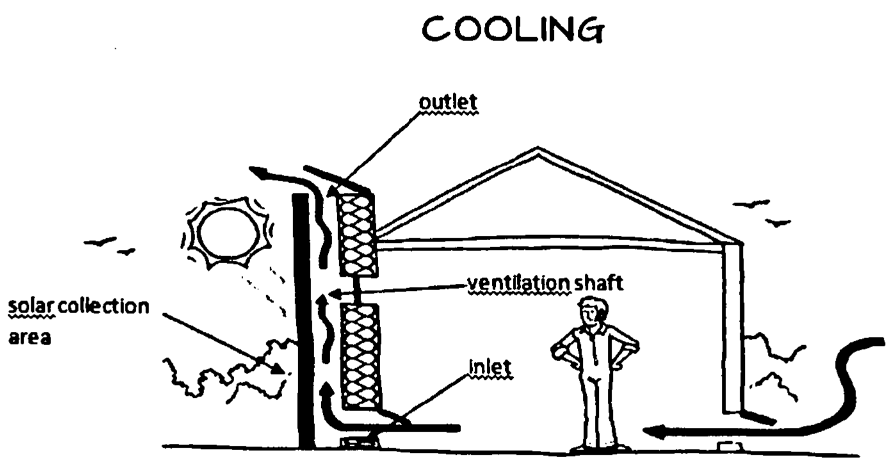

Figure 1.1: Working Principle of Solar Chimney to Improve Ventilation

Source: Autodesk Education Community

1.2 Problem Statement

The performance of the solar chimney depends on the height of the chimney or stack height. For a largest differential pressure between the inlet and outlet of the chimney, a larger stack height is required. However, the larger the stack height, the more difficult chimney maintenance and installation will be, which is not exactly cost efficient. Therefore, the suitable option to resolve the issue mentioned above is to modify the usual vertical solar chimney into an inclined solar chimney.Some efforts have been made by the researchers to investigate the performance of an incline solar chimney experimentally as well as theoretically.

Sakonidou, Karapantsios, Balouktsis and Chassapis (2007) completed a research in modeling the optimum tilt of an inclined solar chimney for maximum air flow. A composite model is also developed to estimate the yields of the natural air flow through solar chimney for different tilt angle. From the research, it was found out that the local temperatures get higher as the tilt angle gets lower and that higher air flow velocities were achieved at a tilt angle of 60°. Mathur, Mathur and Anupma (2006) had also evaluated the performance of the inclined solar chimney during summer and concluded that the optimum tilt of the solar chimney in Jaipur, India would be 45°. Bassiouny and Korah (2009) had also found out that at latitude of 28.4°, the optimum flow rate was achieved in the inclined solar chimney when the chimney inclination was between 45° and 70°.

Although solar energy has very good prospect in Malaysia but most of the research was done on solar chimney drying system of related this issues. There is no topics is found which discussed about suitable tilt angle for solar chimney that enhance ventilation for commercial and residential building in Malaysia.

1.3 Objectives

Objectives are milestones that are set in order to accomplish a task. Hence, it is essential to set objectives for a project so as to ensure that it will be accomplished. The objectives for this project titled "Investigating the Temperature Profile on an Inclined Solar Chimney (ISC)" are as follows:

- Design and develop a inclined solar chimney system for house ventilation
- Develop a empirical relation to determine the heat transfer rate across the inclined solar chimney
- Evaluate performance of inclined solar chimney for different inclination angle under Malaysian climate

1.4 Scope of work

The scope of work is as follows:

- For this research, the experimental work will be done in Kota Kinabalu, Sabah.
- Under this project the empirical model will be developed base on theoretical results and validate it with experimental results.
- The inclination angle of the solar chimney will be varied from 30° to 60°
- The experiment will be conducted during day time only
- The air flow rate will be measured at inlet and estimated at outlet by using conservation of mass law.
- Performance of the solar chimney will be evaluated base on volumetric flow rate

1.5 Methodology

By means of the knowledge of heat transfer and fluid dynamics, the mathematical model for the inclined solar chimney will first be deduced in order to carry out other related activities. As for the design of the inclined solar chimney, it will be drawn using the SOLIDWORKS software and it will fabricated according to the drawing. Once the model is produced, it will be tested in order to obtain experimental results to compare with the results obtained from the simulation. Figure 1.2 shows the flow chart below shows the methodological work flow of this project.

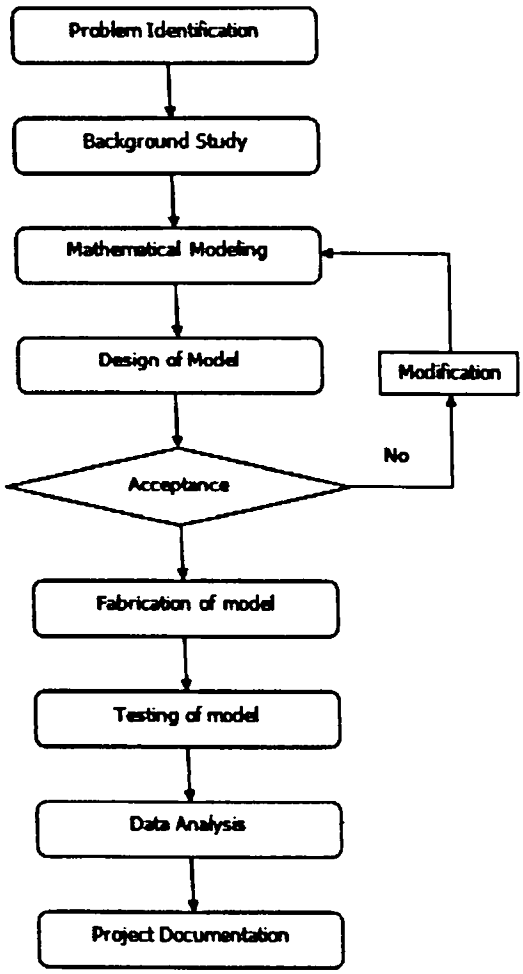

Figure 1.2: Methodological Flow of Project

1.5 Expected Outcome

One of the expected outcomes of this research work would be that the research work for inclined solar chimney can be improved. The temperature profile of the solar chimney under the weather and climate of Kota Kinabalu, Sabah can be investigated as well as compared with the results obtained from the simulation and the performance of the solar chimney can also be known.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter would firstly discuss about the history and the development of solar chimney as well as inclined solar chimney. The improvement of the solar chimney which included the expansion of the uses of solar chimney in different areas are also going to discuss in this chapter. The working principle of solar chimney and inclined solar chimney is also highlighted in brief under this chapter. In order to so do, related journals, articles, books as well as research papers were reviewed to identify the current findings done by other researchers and consequently from there the methodology of this project may be developed. The findings done by the researchers would be cited in this chapter to provide a clearer perspective regarding solar chimney.

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