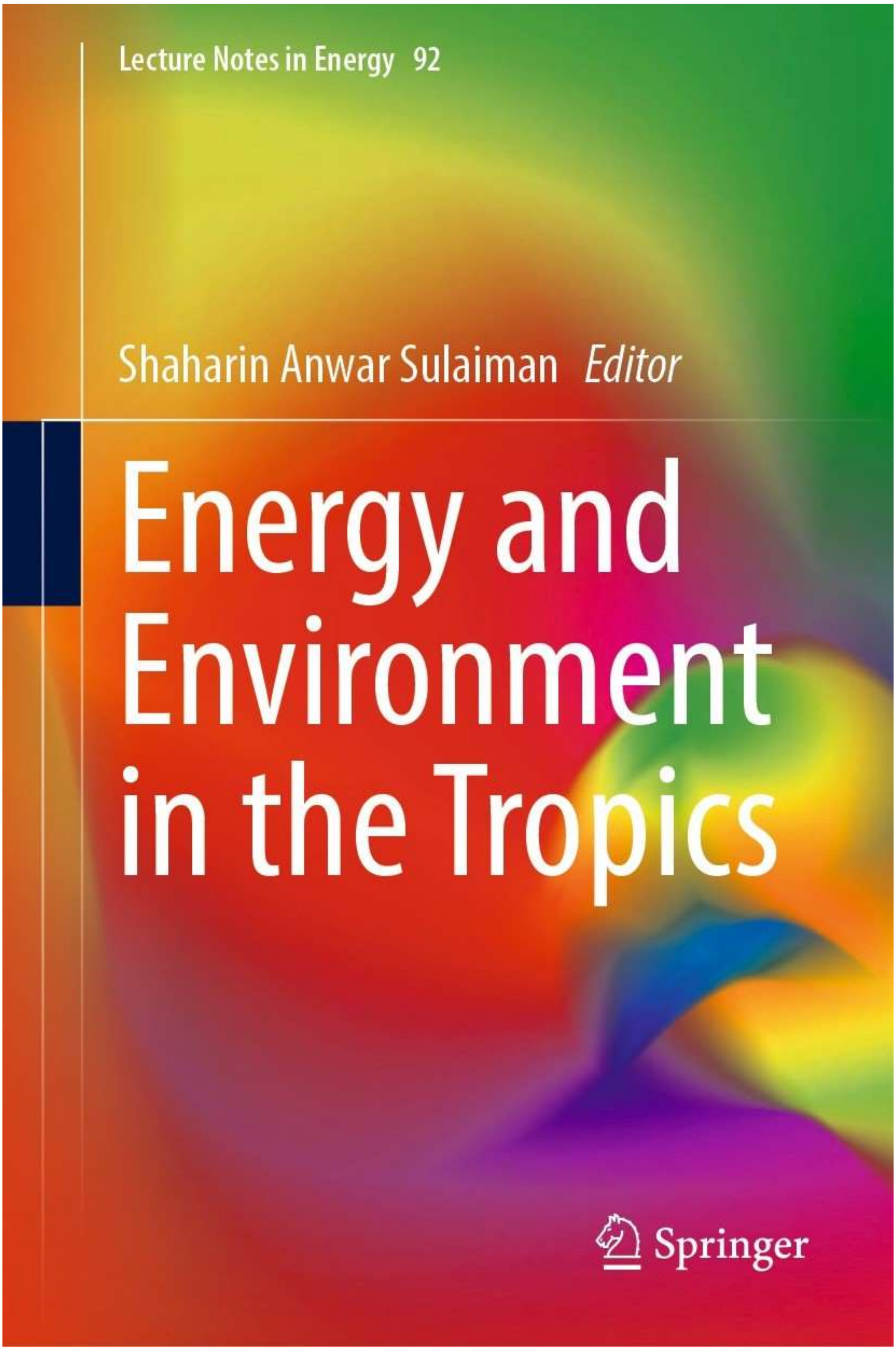

Energy and Environment in the Tropics

edited by: Shaharin Anwar Sulaiman

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Springer

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ISSN 2195-1284 ISSN 2195-1292 (electronic)
Lecture Notes in Energy
ISBN 978-981-19-6687-3 ISBN 978-981-19-6688-0 (eBook)
https://doi.org/10.1007/978-981-19-6688-0

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Preface

Since the 1980s, the terms global warming and climate change were brought up to alert the whole world on an upcoming crisis. It was not well accepted at the beginning, although the awareness was slowly increasing. By now in 2022, the observed rise in temperature and greenhouse gas concentrations has been at the fastest rates in Earth's history. The consequences for these are becoming more distinct. The sea level is clearly raising, submerging certain areas of low elevations. More rains and storms can be seen than before, as well as drought. At the same time, desertification of land is expanding leading to less fertile areas for agriculture, which are needed to support the fast-growing population. By the end of the Great Coronavirus Pandemic of 2019–2021 (COVID-19), a few difficult situations emerged such as the Russia-Ukraine conflict and the early sign of food crisis. The latter could lead to famine. The world economy is also badly hit. Clearly today, the environment, which was perceived differently in the 1980s, coupled with the certain unpredicted situations is making the world's future to become uncertain.

A decade ago, the environmental problems were always expressed as a secondary matter after the mention of energy shortage issues. However, presently, the environment is regarded as a far more important issue due to the many negative effects experienced by many countries. In managing today's problems of environment and energy necessitates various efforts by various stakeholders. In the tropics, this would be unique due to diverse conditions of the areas such as climate, geographical, culture and political conditions. Mitigating the environmental problems in the tropics among others involves enhancing the potential of various types of fuels and conversion of energies. Simultaneously, how the energy is utilized must also be considered holistically. Nevertheless, awareness on the need to improve energy efficiency and to protect the environment is still lacking in many parts of tropical countries. There are plentiful of efforts required within the tropical countries in order to catch up with the vision aspired in the Paris Agreement in 2015. This book delves into studies on issues related to the environment and energy in the tropics. The chapters are contributed by authors from several tropical nations who are experts in the environment and energy topics in their respective countries. The book covers topics in relation to the present state of the environment in selected countries, mainly in Malaysia and the Philippines.

The major content of the book is on the potential energy conversion technologies that can be leveraged for different countries in order to alleviate environmental problems particularly in the tropics. Topics on indoor air quality and energy efficiency, which affect the environment of today, are also presented in this book.

The editor wishes to express his gratefulness to all the contributing authors for their strong effort in preparing the texts for this book. It is hoped that the book would serve as a useful reference to readers.

Seri Iskandar, Malaysia Shaharin Anwar Sulaiman

Contents

Natural Ventilation in Traditional Malay House: A Study of Flow Pattern by an Enhanced Smoke Wire Technique

Nurizzatul Atikha Rahmat, Kamil Khalili Haji Abdullah, and Khairun Adhani Khairunizam

The present work focuses on the qualitative study of flow patterns behind a traditional Malay house utilizing the smoke wire technique with enhanced control dripping and tensioner systems in a small-scaled quasi-atmospheric boundary layer wind tunnel. The controlled drip valve system is utilized to deliver a continuous smoke flow by dripping down water-based solution onto 10 nichrome wires in series. The wires are held down by the spring tensioner system to compensate for the wires' expansion when heated to produce continuous and dense smoke lines.

1 Overview of Natural Ventilation in Traditional Malay House

In the modern world, households are more likely to have air conditioning systems to cool down the house to a comfort level (25.5–28 °C), especially in places with hotter climates [1]. They contribute to the high energy consumption of households, which takes up around 30% of the total energy consumption, which lead to environmental concerns [2]. However, Traditional Malay Houses (TMH) can be cooled through natural ventilation systems, which eliminates the need for an air-conditioning system. They are usually described as comfortably cool even without using any air-conditioning system. Although they are highly dependent on the external temperature, TMHs could reach the range of comfort levels through only natural ventilation [3]. In another study, TMHs have temperatures 1–3 °C higher than modern during

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S. A. Sulaiman (ed.), *Energy and Environment in the Tropics*, Lecture Notes in Energy 92, https://doi.org/10.1007/978-981-19-6688-0_18

To conduct a qualitative investigation on the flow pattern around buildings, several measurement methods are employed, such as three-dimensional measurement, namely, Laser-Doppler Anemometry (LDA) [22], Particle Image Velocimetry (PIV) [23], and the widely utilized two-dimensional hot-wire anemometer [24]. However, the hot-wire anemometer is limited to only two dimensions and would not be suited for the qualitative flow pattern study. Alternatively, another three-dimensional measurement approach that can be utilized to capture flow pattern around buildings very well is the smoke-wire technique (SWT). The SWT utilizes fine aerosol filaments that are produced by heating a wire coated with oil to visualize the flow. It is comparatively less expensive and less complicated to run compared to the LDA and PIV where flow pattern could easily be seen and captured by cameras without the need for additional equipment and post-processing. In most cases, SWT is used in low-speed wind tunnels; however, it has also been used in transonic speeds [25]. However, SWT is also known to have its own limitations. In previous works, SWT is limited to only a single wire, which uses a manual dripping system [26, 27]. However, improvements have been made to SWT that automatically supplies the smoke fluid to 10 separate smoke wires. In 1992, Wu found that the smoke wire will cause the airflow to become fixed vortex pair [28]. Other than that, like a filament lightbulb, the smoke wire tends to burn when excess power is out into them [29]. In addition, the movement of the smoke would be blurry if it is recorded at a cinematic frame rate (24 frames per second). Thus, high-speed recording will help with reducing the motion blur [30].

The SWT would be able to visualize the flow pattern that we would expect around rectangular buildings. They are highly complicated patterns that are defined by impingement, separation, reattachment, circulation, and vortices. There are several main flow patterns that are usually observed around a rigid body. They are horseshoe vortex, Karman vortex, flow separation, stagnation point, wake region, and mean cavity reattachment line [31, 32]. A larger rectangular building with the main face rising clearly from the ground has shown to be problematic due to the horseshoe vortex that is created on the ground level [32]. However, TMHs do not have a main face rising from the ground as they are built on stilts. Thus, it will be interesting to observe the flow pattern of TMHs, as the qualitative research on flow patterns around TMHs is very scarce.

Due to the above circumstances and the usage of natural ventilation to reach the range of comfort levels as the motivating factor, the present study will try to fill the research gap by studying the flow pattern around a traditional Malay house in a quasi-atmospheric boundary layer wind tunnel by using an enhanced smoke-wire technique, as the measurement approach. The flow pattern will then be recorded using a high-speed camera to avoid motion blur.

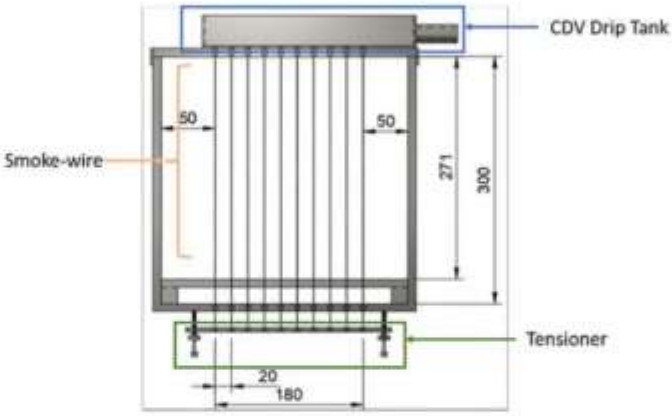


Fig. 2 Schematic of the enhanced SWT with CDV and tensioner system

$$Re = \frac{\rho V_{avg} D}{\mu}$$

which gives:

$$Re = \frac{(1\,\text{m/s})(1.184\,\text{kg/m}^3)(0.3\,\text{m})}{1.849\,\times 10^{-5}\text{kg/m.s}} = 213,449(Turbulent\ Flow)$$

4 Smoke Wire Technique

The flow visualization has been achieved by using an enhanced SWT in which a control dripping valve that continuously supplies smoke fluid, and a tensioner system, to counteract the expanding smoke wire when they are heated, are installed in the experiment. Shown in Fig. 2 is the schematic of the enhanced SWT with CDV and tensioner system, in which 10 nichrome wires with a diameter of 0.4 mm are lined up 20 mm apart in perpendicular to the floor of the wind tunnel. The wires are then heated by passing 250 Watts of power through them.

5 Scale TMH Models

Scale models of TMHs are made to represent them in the BLWT. These models are based on "*rumah ibu*", which is usually the main house is a TMH layout [5, 36]. This includes platforms elevated on stilts [5, 6], large windows and doors [6], and floor with gaps [6]. They are simplified models that only include features needed for the experiment. Thus, some smaller details, such as wall panels with decorative wall panels with holes [5] and opening under roof [6], are omitted due to being too small to be observed in the experiment [1, 3, 4, 6, 37].

To represent multiple configurations of the model that have been created, several parts have been designed and manufactured to be swapped in and out which include:

- 3D printed house frame
- Acrylic solid wall
- Acrylic wall with door
- Acrylic wall with window
- Acrylic roof assembly
- Acrylic 50 mm legs
- Acrylic 100 mm legs

This allows for 324 possible combinations of features. However, there are only 12 combinations that are possible with the parts that have been manufactured and only two will be observed in the experiment to allow for the difference between a TMH without any opening and only one opening to be observed. The two assembly combinations that will be observed are shown in Fig. 3.

As both model houses have the same features other than the door, they could be summarized with the drawing of Assembly B shown in Fig. 4. The placement of the model also plays a role in the experiment. The model would be placed directly placed in the middle of the cross-section of the BLWT with the main face of the model, the face that has angled sections for the roof, directly perpendicular to the direction of the wind. The model would be placed 400 mm away from the smoke wire and 100 mm back from the edge of the platform. This is depicted in Fig. 5.

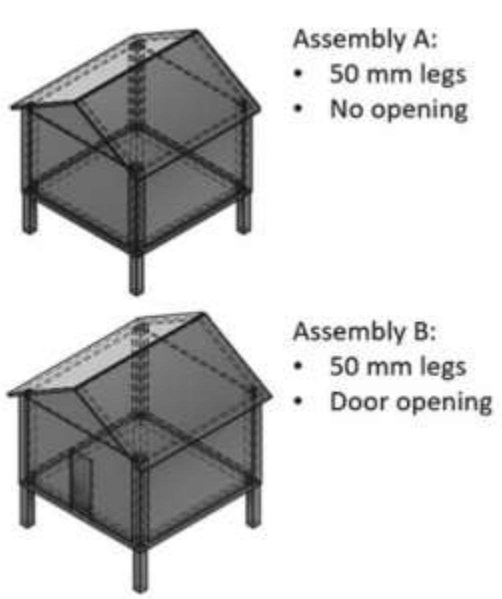
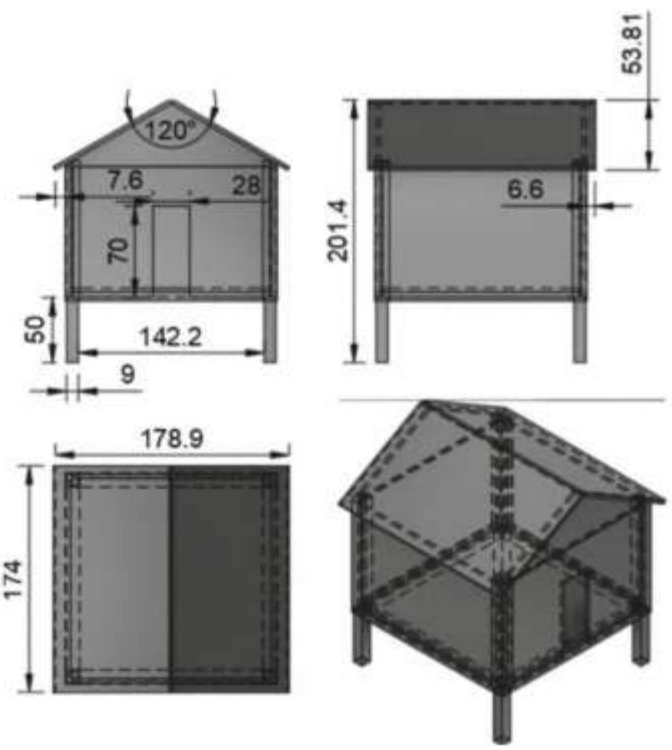


Fig. 3 Schematic drawing of Assembly A, a TMH scale model without any exposed opening and Assembly B, TMH scale model with a door as the only opening

Fig. 4 Schematic drawing of front, top, and side views for model TMH representing Assembly A and B



6 Results and Discussion

The high-speed footage was taken from three different angles, which consist of the side, top, and rear views of the model. Each angle was selected to capture several airflow patterns that could be recorded from the respective angle. The results are represented by pictures in Figs. 6a–f.

From the high-speed footage and instantaneous pictures grabbed from the footage; several flow patterns could be visible. One of the patterns that could be easily seen is the presence of a stagnation point in the middle of the structure paired with upwash, which is visible in Fig. 6a. However, the stagnation point did not develop in the centermost point of the structure with the presence of the door. This is due to the door also being directly in the center of the structure, which aligns with the position of the original stagnation point. This phenomenon could be observed in Fig. 6a and b.

Other than that, a higher velocity of airflow in comparison to other parts of the house has been observed below the floor of the house, which only could be in the high-speed footage but has been represented in Fig. 6a and d. This is due to the flow into a low-pressure wake region. The aforementioned phenomenon would play an important role if there were openings on the floor of the TMH, which is also a distinctive feature that is well known in the design of TMHs. Further experiments on this matter will be held to observe the effect.

The model TMH shows mean cavity reattachment lines parallel to the YZ plane, which could be observed highlighted in Fig. 7. This is also an effect of the raised floor of the TMH, which allows for the air to flow below the structure. However, the

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