UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical Engineering

STUDY THE TEMPERATURE DISTRIBUTION OF SOLAR-POWERED DRYING CHAMBER USING CFD SIMULATION

Shaikh Tahfiq Falahin bin Shaikh Ahmad Hilmy

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SHAIKH TAHFIQ FALAHIN BIN SHAIKH AHMAD HILMY

A report submitted
in fulfilment of the requirements for the Master of Mechanical Engineering

Faculty of Engineering Mechanical

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2021

DECLARATION

I declare that this report entitled "Study the Temperature Distribution of Solar-Powered Drying Chamber Using CFD Simulation" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : Shaikh Tahfiq Falahin bin Shaikh Ahmad Hilmy

Date : 20/4/2021

APPROVAL

I hereby declare that I have read this report and in my opinion this report is sufficient in terms of scope and quality for the award as a partial fulfillment of Master of Mechanical Engineering (MMCE).

Signature : .....

Supervisor Name : Dr. Suhaimi bin Misha

Date : 20/4/2021

IR. DR. SUHAIMI BIN MISHA
PENSYARAH KANAN
FAKULTI KEJURUTERAAN MEKANIKAL
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEDICATION

Specially dedicated to my beloved family

ABSTRACT

Solar drying technique had been around from the beginning of civilization and continue to be used up to these days. Throughout the years, the development of new technology had seen the wide varieties of solar drying techniques. The most basic being the open drying technique which used up a lot of spaces and slow drying process. The invention of solar dryer marks the development in the solar drying techniques. The solar dryer can be classifies as passive, active and hybrid solar dryer. Throughout the years, development of solar dryer has taken a significance advancement. The use of software such as ANSYS and Matlab is a common practice to designed a solar dryer nowadays. This paper focused on the use of ANSYS software to simulate the solar dryer operation and study the temperature distribution of three design of solar dryer. The design consist of solar dryer with no reflector, 45° reflector and 60° reflector. The drawing of the solar dryer was done using DesignModeler then will be given boundary condition and appropriate meshing process. Simulation of the solar dryer is done using Monte Carlo solar load model and two direction of sun beam was analyzed. The result for temperature distribution were taken from points, points cloud and volume rendering techniques. All of the result then analyzed and compared to each other to determine the best design for the solar dryer and the optimum operating condition. The simulation conclude that solar dryer with 45° reflector give the best temperature distribution when operating with the sun beam come directly from above and 45° from the side. The design of solar dryer with reflector on both side also yield better result compare to solar dryer with no reflector.

ABSTRAK

Teknik pengeringan solar sudah ada sejak awal peradaban dan terus digunakan hingga hari ini. Selama bertahun-tahun, pengembangan teknologi baru telah melihat pelbagai teknik pengeringan solar dibangunkan. Teknik yang paling asas adalah teknik pengeringan terbuka yang menggunakan banyak ruang dan proses pengeringan perlahan. Perciptaan pengering solar menandakan perkembangan dalam teknik pengeringan solar. Pengering solar boleh dikategorikan sebagai pengering suria pasif, aktif dan hibrid. Selama bertahun-tahun, pembangunan pengering solar telah menunjukkan kemajuan mendadak. Penggunaan perisian seperti ANSYS dan Matlab telah menjadi amalan biasa dalam merekacipta pengering solar pada masa kini. Makalah ini akan memfokuskan pada penggunaan perisian ANSYS untuk mensimulasikan operasi pengering solar dan mengkaji taburan suhu tiga reka bentuk pengering solar. Reka bentuknya terdiri daripada pengering solar tanpa reflektor, reflektor 45° dan reflektor 60°. Lukisan pengering solar akan dilakukan menggunakan DesignModeler kemudian akan diberikan 'boundary condition' dan proses 'meshing' yang sesuai. Simulasi pengering solar akan menggunakan model muatan solar Monte Carlo dan dua arah sinar matahari akan dianalisis. Hasil pengagihan suhu akan diambil dari titik yang telah ditetapkan, gerombolan titik secara rawak dan teknik rendering isipadu. Semua hasilnya kemudian akan dianalisis dan dibandingkan antara satu sama lain untuk menentukan reka bentuk terbaik untuk pengering solar dan keadaan operasi yang optimum. Simulasi menyimpulkan bahawa pengering suria dengan reflektor 45° memberikan taburan suhu terbaik ketika beroperasi dengan sinar matahari datang langsung dari atas dan 45° dari sisi. Reka bentuk pengering solar dengan reflektor di kedua sisi juga memberikan hasil yang lebih baik berbanding dengan pengering solar tanpa reflektor.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

PV	Photovoltaic
CFD	Computational Fluid Dynamic
DO	Discrete Ordinate
3D	Three dimensional

LIST OF SYMBOLS

°	Degree
°C	Degree Celsius
MW	Megawatt
kW/m	Kilowatt per meter
%	Percent
mm	Millimeters

CHAPTER 1

INTRODUCTION

1.1 Project Background

Harnessing the solar energy as a renewable and infinite source of energy has always been the goal for many researchers in the energy industries. The use of solar in the agriculture and food preservation is well documented throughout the years. Open solar drying is considered among the oldest method for preservation of agricultural and marine product. The use of solar as main source of energy is economically reasonable as it require almost little to no cost at all and it also a renewable source of energy. However, open solar drying technique also come with many disadvantages such as the use of large area, contamination of product and longer time taken to complete the drying process (Hossain *et al.*, 2018). Therefore, many research and development had been done to maximise the potential and use of solar dryer. There are several types of solar dryer technologies such as passive solar dryer, active solar dryer and hybrid solar dryer. All of these technology come with their respective advantages and disadvantage (Sontakke and Salve, 2012).

Drying of agriculture and marine product mean the removing of moisture from the food product and surroundings. These process use the heat and mass transfer simultaneously in which the use of energy is needed (Sontakke and Salve, 2012). The drying process also dependent on many factors such as the humidity, drying rate and temperature. For example, the moisture in the agricultural product removed by heated air at temperature range from 50° to 60° (Kumar, Sansaniwal and Khatak, 2016).

This research will focus on the use of air-based solar dryer. There are many important part in a solar dryer system such as PV collector, drying chamber, fan, air duct, auxiliary unit and etc. The use of solar dryer is dependent on the weather and the intensity

of radiation. The intensity of radiation is known not to be constant throughout the days. The efficiency of solar dryer also dependant on the location, velocity, humidity and surrounding temperature (Lingayat, Chandramohan and Raju, 2017). There are many technology that been developed to overcome these limitation. One of the technologies is the use of solar tracking so the solar dryer can get constant radiation from the sun hence increasing it drying performance. However, this technology considered to be uneconomical and expensive to be use in agriculture solar dryer. Therefore, the design of the drying chamber need to be optimised such as the use of reflector to direct the sun radiation to the drying chamber.

This research will use the ANSYS software to do a CFD simulation to determine the optimum angle of reflector so that the drying chamber has an even temperature distribution and can operate at maximum capacity consistently. The result of the simulation then will be compared with the experimental result for validation purpose. The simulation also will give a better idea and insight as for the air flow and the temperature distribution in the drying chamber so that solar dryer can be operate at optimum condition.

1.2 Problem statement

The use of solar dryer as an alternative for open solar drying technique had been around for a long time. The use of solar dryer come with many advantages in comparison with open drying technique. However, there is still some limitation in the use of solar dryer. These limitations such as the dependent on the sun position and weather condition always been a big hurdle for an effective operation of solar dryer. The power produced by sun that received by the Earth is approximately 1.8 x 1011 MW. However, the solar radiation flux that can be harness rarely exceed 1 kW/m even in the hottest region. Therefore, solar tracking technology is developed to rectify this problem. Solar tracker will move the solar panel perpendicular to the sun direction throughout the day (Racharla and Rajan, 2017)(Racharla and Rajan, 2017). This ensure that the solar panel can harness the maximum amount of solar energy throughout the days. However, the use of solar tracking system is expensive and unaffordable to be use in agriculture solar dryer. Hence, reflector is use as an alternative to the solar tracking system. Theoretically, the reflector will concentrate the sun radiation toward the drying chamber which will ensure the temperature inside the drying chamber remain high regardless of the sun position.

The use of reflector in the drying chamber design need to be optimized to ensure that the solar dryer operate at the best possible condition. These mean that the position of the reflector need to be at the best possible angle to give maximum radiation toward the drying chamber. In order to obtain the data, an experiment need to be done and this prove to be costly as an actual solar dryer with different angles of solar reflector need to be fabricate. It is also a time consuming process. Therefore, the use of software is consider to be an effective alternative to solve this problem. The use of software such as ANSYS and Matlab is commonly use to simulate this type of problem. The use of software can help researcher to get better understanding of the functionality and predicting the solar dryer

performance. Computational fluid dynamics can be used to simulate the air flow and temperature distribution by using the suitable simulation of ANSYS and FLUENT (Singh Chauhan, Kumar and Tekasakul, 2015). Besides that, there is also other software such as adaptive network based fuzzy inference system (ANFIS) that can be used for this type of simulation (Prakash *et al.*, 2016). However, this research will focus on using the ANSYS and FLUENT software to simulate the drying chamber temperature distribution. Besides that, there only several locations inside the solar dryer that will be installed with sensors for the experiment. Hence, the temperature at the location without the sensors remain unknown. By using simulation, the detail of temperature can be analysed in the drying chamber. The result from the experiment will be use to validate the simulation.

1.3 Objective

The aim of this research is to find the optimum angle of reflector so that the solar dryer can be operated at high efficiency. Thus, the objectives are:

1. Find the optimum angle of reflector using ANSYS simulation.
2. Determine the temperature distribution in the solar dryer.
3. Compare the result of solar dryer with and without reflectors.

1.4 Scope

The scope of this project is to use ANSYS software to compute the solar reflection and temperature distribution in the solar dryer. The angle of reflector will be simulate at three different angles which are no reflector, 45° and 60°. The sun position for the simulation will be directly above the solar dryer and 45° to the side of solar dryer. The temperature distribution in the solar dryer will be compute in the post result simulation to study the uniformity of the dried product.

1.5 General methodology

The description and details of methodology to achieve the objective will be explained in Chapter 3. Generally, the flow in order to accomplish this project are as follows;

a) **Literature review**

Collecting data from previous studies from the journal, article, book, website any related material about the project.

b) **Drawing of solar dryer design**

Draw based on real model using SolidWork software. The design and dimension is done precisely in order to conduct the simulation precisely.

c) **Simulation using ANSYS software**

Simulate using ANSYS fluent with solar load model. This include the use of DesignModeler, Meshing, FLUENT and CFD-Post.

d) **Report writing**

A written report detailing the simulation data and analysis is to be completed.

CHAPTER 2

LITERATURE REVIEW

2.1 Solar Energy

Energy have always been a concern in today's world. There always research for improvement and developing a new way to obtain energy. Fossil fuel had always been the main source of energy for mankind. A research say that fossil fuel contribute to 80% of world's need (Huang, Zhou and Lin, 2011). This is an alarming figure as the decreasing number of source for fossil fuel over years and environmental issues cause by fossil fuel. Fossil fuel come from ancient animal and micro-organism which can take up to million years to form. Hence, it fall as non-renewable energy sources. In the recent years, the world energy demand is growing exponentially as the result from population growth, industrial activities and technological advancement (Kannan and Vakeesan, 2016). Therefore, renewable resources of energy had been study throughout the years by many researchers in order to provide an alternative and replace the conventional fossil fuel. One of the promising renewable source of energy is solar energy. Solar energy can be access from everywhere and abundantly available for free. It also can be exploited directly to generate electricity and provide us with a clean source of energy (Mekhilef *et al.*, 2012). Besides that, there are several other benefits of solar energy such as minimal maintenance and long life span which can be in range of 20 to 30 years (Kabir *et al.*, 2018).

The wide varieties that solar energy can be used for is one more reason that made it a promising prospect for renewable energy source. Direct conversion to electricity is one of the application for solar energy but solar also widely use as heat source for solar dryer or solar heater system (Kannan and Vakeesan, 2016). The conversion of solar energy mainly