



**Faculty of Mechanical Engineering**

**LOW COST NATURAL CONVECTION SOLAR DRYER FOR  
DRYING DURIAN TREE WOOD**

**Afiqah Binti Ngah Nasaruddin**

**Master of Mechanical Engineering (Energy Engineering)**

**2017**

## **APPROVAL**

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality as a partial fulfillment of Master of Mechanical Engineering (Energy Engineering).

Signature : .....

Supervisor Name : .....

Date : .....

**LOW COST NATURAL CONVECTION SOLAR DRYER FOR DRYING DURIAN  
TREE WOOD**

**AFIQAH BINTI NGAH NASARUDDIN**

**This thesis submitted in fulfillment of the requirement for the degree of  
Master of Mechanical Engineering (Energy Engineering)**

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ii

## DECLARATION

I declare that this thesis entitled “Low cost natural convection for drying durian tree wood” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

*Dedicated to:*

*Mom and dad*

*Dearest Friends*

*(razin, nazrin, ima, bahrom) who in the same journey towards the same destinations*

*And to Whom It May Concerned*

*“THANKS FOR ALWAYS ENCOURAGING AND SUPPORTING ME”*

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## ABSTRACT

The study is about developing and evaluating the performance of natural convection mode of solar dryer by the application of indirect solar energy to dry a durian tree wood. The main idea for the study is to come with the alternative replacement of the old method of open sun drying system with the one that offer low capital cost, less time required for drying, secured and more efficient in term of performance. Previously researcher has identified several parameter that affect the performance of the solar dryer mainly based on the design, load, absorber, chimney and location of the study that affect weather condition. Apart from that, from the evaluation of performance of the solar dryer show that it is capable for the solar air collector to reach efficiency of 4.72 when the average temperature of  $30^{\circ}\text{C}$  is recorded based on the calculation. While, the time required for a thin layer of durian tree wood to dry using open sun drying is approximately four hours compared to only 2 hours and 20 minute when using designated solar dryer. Result for the simulation of solar dryer using both ANSYS and TRNSYS software is showing that the expected temperature for the ideal condition of solar dryer while the economical analysis on solar dryer gave the payback period of 22 days and ROI of 41.6 %. The validation of the result is made by comparing the maximum, minimum and the average temperature obtain from simulation using software and the experiment which proves that the experimental results are being verified despite a small reasonable difference.

## ABSTRAK

Kajian ini adalah untuk membina dan menilai prestasi pengering solar dalam mod perolakan semulajadi dengan menggunakan tenaga solar secara tidak langsung untuk mengeringkan kayu pokok durian. Idea utama kajian ini adalah untuk mencadangkan penggantian kaedah lama iaitu sistem pengeringan matahari terbuka dengan kaedah yang menawarkan modal yang rendah, singkat masa pengeringan, lebih selamat dan cekap dari segi prestasi. Sebelum ini penyelidik telah mengenal pasti beberapa faktor yang memberi kesan kepada prestasi pengering solar terutamanya berdasarkan reka bentuk, beban, penyerap, cerobong dan lokasi kajian yang memberi kesan kepada keadaan cuaca. Selain itu, dari penilaian prestasi pengering solar menunjukkan yang ia mampu mencapai kecekapan 4.72 a a il a suhu ura ta C direkodkan berdasarkan pengiraan. Walaupun, masa yang diperlukan untuk lapisan nipis kayu pokok durian kering menggunakan terbuka pengeringan matahari adalah lebih kurang empat jam berbanding hanya 2 jam dan 20 minit apabila menggunakan pengering solar. Keputusan untuk simulasi pengering solar menggunakan kedua-dua perisian ANSYS dan TRNSYS menunjukkan jangkakan suhu untuk keadaan yang ideal bagi pengering solar, manakala analisis ekonomi pada pengering solar memberi tempoh bayar balik selama 22 hari dan ROI sebanyak 41.6%. Pengesahan keputusan kajian telah dilakukan dengan membandingkan maksimum, minimum dan suhu purata yang didapati daripada simulasi menggunakan perisian dan eksperimen di mana ia membuktikan bahawa keputusan eksperimen dapat disahkan walaupun terdapat perbezaan kecil yang munasabah.



## TABLE OF CONTENT

	<b>PAGE</b>
<b>APPROVAL</b>	<b>i</b>
<b>TITLE PAGE</b>	<b>ii</b>
<b>DECLARATION</b>	<b>iii</b>
<b>DEDICATION</b>	<b>iv</b>
<b>ACKNOWLEDGMENT</b>	<b>v</b>
<b>ABSTRACT</b>	<b>vi</b>
<b>ABSTRACT</b>	<b>vii</b>
<b>TABLE OF CONTENT</b>	<b>viii</b>
<b>LIST OF FIGURES</b>	<b>xi</b>
<b>LIST OF TABLE</b>	<b>xiv</b>
<b>LIST OF ABBREVIATION</b>	<b>xv</b>
<b>LIST OF APPENDIX</b>	<b>xvi</b>
<b>CHAPTER</b>	
<b>1. INTRODUCTION</b>	
1.1 Project Background	1
1.2 Problem Statement	3
1.3 Objective	5
1.4 Scope and Limitation	6
1.5 Significance of Research	7
1.6 Overview	9
<b>2. LITERATURE REVIEW</b>	
2.1 Solar Thermal	10
2.1.1 Irradiation and Peak Sun Hour	11
2.1.2 Sun Orientation	12
2.1.3 Tilt Angle for Solar Collector	12

2.1.4	Weather data/Condition	12
2.2	Open Sun Drying	14
2.3	Stack Effect/Air Buoyancy	16
2.4	Drying Mechanism	18
2.4.1	Air Properties	20
2.4.2	Moisture Content	21
2.4.3	Properties of Durian Tree Wood	22
2.5	Solar Drying System	25
2.5.1	Indirect/Direct Solar Dryer	25
2.5.2	Natural Convection	27
2.5.3	Forced Convection	27
2.5.4	Hybrid Solar Dryer	28
2.6	Crop Database	28
2.7	Previous Research	31
2.7.1	Natural Convection	31
2.7.2	Forced Convection	34
2.7.3	Hybrid Solar Dryer	37
<b>3.</b>	<b>METHODOLOGY</b>	
3.1	Project Flowchart	40
3.2	Step for Solar Dryer Design and Evaluation	42
3.2.1	Design Calculation	43
3.2.2	Instrument Application	49
3.3	Computer Simulation	52
3.3.1	TRNSYS	53
3.3.2	ANSYS	57
3.4	Solar Dryer Description	60
<b>4.</b>	<b>RESULT AND DISCUSSION</b>	
4.1	Evaluation of performance of Solar Dryer	63
4.1.1	Part A : [cloudy day/shiny surface]	64

4.1.2	Part B : [sunny day/painted black]	69
4.2	Sample Calculation	73
4.2.1	Part A: Calculation for heat transfer	73
4.2.2	Part B: Energy Related Calculation	77
4.2.3	Part C: Calculation for Dryer Efficiency	79
4.3	Computer Simulation part 1 :TRNSYS	81
4.4	Computer Simulation Part 2 :ANSYS	85
4.4.1	Solar Collector	85
4.4.2	Drying Chamber	90
4.5	Economic Analysis	98
4.5.1	Capital Cost of Solar Dryer	99
4.5.2	Payback Period	100
4.5.3	Return of Investment	101
4.6	Validation of Result	102
4.7	Result and Discussion	103
4.8	Design Effect	106
<b>5.</b>	<b>CONCLUSION AND RECOMMENDATION</b>	
5.1	Conclusion	108
5.2	Recommendation	110

## **REFERENCES**

## **APPENDICES**

## LIST OF FIGURES

<b>FIGURE</b>	<b>TITLE</b>	<b>PAGE</b>
1.1	Open sun drying of durian tree wood	4
2.1	Open sun drying working principle	16
2.2	Stack effect in designated solar dryer	17
2.3	Drying rate with time curve	18
2.4	Moisture in drying material	19
2.5	Representation of drying process	20
2.6	Direct/natural convection solar dryer	32
2.7	Box-type absorber collector natural convection solar dryer	33
2.8	Forced convection mode solar dryer	34
2.9	Double pass V-groove collector	35
2.10	Desiccant based solar dryer	36
2.11	Water heater bed hybrid solar dryer	37
2.12	Rock bed hybrid solar dryer	38
2.13	Multi-pass build in thermal storage dryer	39
3.1	Project flow chart	41
3.2	Pico data logger, thermocouple	50
3.3	Veloci-calc plus	51
3.4	Application of moisture detector	52

3.5	Component available in TRNSYS library	54
3.6	The parameter required for component of weather data reading and processing Type 15.6	55
3.7	The parameter required for solar air collector Type 561	55
3.8	The parameter required for drying chamber Type 60m	56
3.9	The parameter required for output processing Type 65d	57
4.1	Solar dryer before painted black	65
4.2	Graph of temperature at different point at solar dryer for experiment 1	68
4.3	Solar dryer after painted black	70
4.4	Graph of temperature at different point at solar dryer for experiment 2	72
4.5	Wall representation for solar collector	74
4.6	Thermal resistance network for series arrangement	74
4.7	Schematic diagram for design solar dryer	82
4.8	Relation between component's output in TRNSYS	82
4.9	Average temperature inside drying chamber predicted for one whole day	83
4.10	Average temperature, internal energy and flow rate of a solar dryer predicted for 7 days	84
4.11	The geometry of solar collector in ANSYS workbench	86
4.12	Face meshing of the solar collector	87
4.13	The volume rendering of solar dryer	88
4.14	The temperature distribution contour of solar collector	89

4.15	Geometry of drying chamber in ANSYS workbench	90
4.16	Face meshing of drying chamber	91
4.17	Velocity streamline representation of drying chamber for case 1	93
4.18	Velocity streamline representation side view for case 1	93
4.19	The volume rendering of drying chamber for case 1	94
4.20	Velocity streamline representation of drying chamber for case 2	95
4.21	Velocity streamline representation side view for case 2	96
4.22	The volume rendering of drying chamber for case 2	97
4.23	Instrument application for solar dryer evaluation of performance	104

## LIST OF TABLE

<b>TABLE</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	Monthly averaged insolation incident on a horizontal surface	13
2.2	Monthly averaged wind speed at 50,100, 150, and 300 m above the surface of the earth	14
2.3	Seasoning properties of different species of durian tree wood	23
2.4	Schedule D of kiln-drying recommendation for durian timber	24
2.5	Moisture content of solar drying of various agricultural products	28
2.6	Mean moisture content of specimens dried at different temperatures and the range of moisture content values	30
3.1	Parameter need to be setting-up	59
3.2	Description of material involve for the construction of solar dryer	61
3.3	Design condition and assumption related on solar dryer	62
4.1	Temperature at different point of solar dryer in 5 minutes interval for experiment 1	66
4.2	Temperature at different point of solar dryer in 5 minutes interval for experiment 2	71
4.3	Cost for developing solar dryer	99
4.4	Cash flow investment	100
4.5	Comparison between ANSYS, TRNSYS and experimental in term of temperature	103

## LIST OF ABBREVIATION

CFD	-	Computational Fluid Dynamics
FKM	-	Fakulti Kejuruteraan Mekanikal
FRIM	-	Forest Research Institute Malaysia
KMKM	-	Kompleks Makmal Kejuruteraan Mekanikal
MC	-	Moisture Content
NASA	-	National Aeronautics and Space Administration
POWER	-	Prediction of Worldwide Energy Resources Project
ROI	-	Return of Investment
TRNSYS	-	Transient System Simulation
UV	-	Ultra Violet



## **LIST OF APPENDICES**

1. Letter to the Dean
2. Weather data 2015/2016
3. NASA surface meteorology and solar energy
4. Project gantt chart
5. Work progress

## CHAPTER 1

### INTRODUCTION

#### 1.1 Project Background

Different types of solar dryer have been designed, developed and tested in the different region (Bala *et al.*, 2012). Two major categories of the dryers are natural convection and forced convection type of solar dryer. For natural convection solar dryers, the airflow is established by buoyancy induced airflow while for forced convection solar dryers the airflow is provided by using fan operated either by electricity or fossil fuel. Although open sun drying of the agricultural products on concrete floor is considered as cheap and moderately successful being employed specifically for this case study specimen which is durian tree wood. Even though, the open sun drying is the simplest and cheapest method available however, in the mean time the solar radiation and climatic condition are something beyond control by nature.

The aim of drying is to remove moisture from the agricultural product so that it can be processed safely to any end product desired. Moreover, wood drying is one of the step wood treatments with the intention of preventing its destruction by wood-decaying organisms. As a matter of fact, with the appropriate preservative it will somehow increase the service life of wood-based product along with their aesthetic qualities and in the mean time helps to conserve our nation's timber resources from going to waste. Thus, by providing a sheltered

drying compartment or chamber in which the agricultural product to be dried are stored. Subsequently, a stream of air is heated by solar energy to reduce its relative humidity which is then passed over durian tree wood. This form of solar drying approach were expected to improve the quality of the crop to be dried, reduce contamination and speed up drying process thus, achieve better quality control and reduction in time taken for drying.

It is inappropriate dryer design due to the choice of construction materials and inadequate understanding of the operation of solar dryers and lack of design procedures contribute to poor performance of natural convection type of solar dryer (Komolafe *et al.*, 2011). Designs of natural flow dryers require an understanding of overall operation of dryer such as the interaction between it component and their influence of operating parameter on its performance.

## 1.2 Problem Statement

Deterioration of wood are the effects from the hot and humid weather in Malaysia in addition to other factors such as fungi and other insect for example termites and carpenter ant that may deteriorate the wood and cause might reduce wood service life (Highley, 1999). This common threat from the fungi digesting cellulose and other component of wood for food thus result with soft and crumbly wood that low in strength. Since the favourable condition of fungi spreading is temperature between 20 to 35° C, moisture content of wood over 20%, presence of oxygen and cellulose thus make all wood are vulnerable to this threat. Any of the condition describe need to be eliminated so that the decay fungi cannot grow and the wood is protected from decaying (Hoffman *et al.*, 2016).

In this case study the approach taken are to eliminate two of the optimum condition of fungi growth which is rising the temperature above the range that favourable for fungi to growth and remove the moisture content to be in between 6-10 % which is below than 20 % since fungi need sufficient moisture to decay wood. Thus, drying process of wood is essential before proceeding with next step of wood treatment before the end wood-based product to be developed since excess moisture content prevent uniform penetration for wood preservatives and retention.

Drying of agricultural products via method of open-sun drying is still widely applied and in this case study they are spread on concrete floor until sufficiently dried so that they can be stored safely. However, there are several problems related with open sun drying specifically for this case study such as it requires both large amount of space and long drying time in the mean time the crop is susceptible to re-absorption of moisture if it is left on the

floor during periods of no sun, there is no control on the drying process. This could lead to slow drying rate, contamination and poor quality of dried products thus, loss in production. In addition, the natural phenomenon such as the sudden rain and when it comes to rainy season it will interrupt the production of the factory itself.



**Figure 1.1:** Open Sun Drying of Durian Tree Wood

This project will be work on based on the need of its reliability and economically. In addition, the perspective is to design and construct an indirect natural convection mode solar dryer using the specimen as being stated and to evaluate the performance of this solar dryer. Materials can be dried in mass compared to traditional method of open sun drying while laying the agricultural product on the open space. It is undeniable that with the implementation of solar dryer more agricultural product can be dry same time since space needed for drying has been reduced.

### 1.3 Objective

In general, the objective of this case study is to design and run a computer simulation of the optimum low cost natural convection solar dryer and to evaluate its performance. It is also aim for developing a low cost natural convection solar dryer in which the specimen of durian tree wood are dried simultaneously by both direct radiation through the wall of the drying chamber itself and by the heated air from the transparent solar collector. Other objectives of the study are:

- 1) To study the time required to dry a thin layer of Durian tree wood.
- 2) To design a low cost natural convection solar dryer to dry Durian tree wood.
- 3) To fabricate and test the solar dryer at the factory.

## 1.4 Scope and Limitation

This project will focus on the act of designing and evaluating the performance of low cost natural convection solar dryer. It will consist of properly considering every factor that might improve the performance of solar dryer for the application of drying the durian tree wood with consideration of Malaysia's climate generally and Ayer keroh, Melaka specifically. Along the case study, several designs of solar dryer will be tested by implementing a simulation to obtain information such as the heat flux that able to be supplied by different design of solar dryer. The most optimum design of solar dryer will be fabricated and their performance in term of drying the specimen of durian tree wood will be evaluated. The thin layer of wood from the durian's tree is the only specimen of wood that will be tested using the solar dryer. It is to control the parameter such as the moisture content which might be differs from wood species to another.

The fluctuation of averaged solar insulations as in the data retrieved and seasonal doing with geographical dependence are the major challenges in identifying suitable application using solar energy as the heat source. Exploring high efficiency solar energy concentration technology is necessary and realistic. By nature, solar energy is intermittent since there is no sun at night and when cloudy day. The intensity of the sun can be seasonal and is dependent on the meteorological conditions of the location. Unreliability is the biggest retarding factor for extensive solar energy utilization.

## 1.5 Significance of Research

Nature had provided us with abundant of resources to be use in a wise way to benefit daily work or activity without harming the environment in return. The study in the field of solar thermal specifically in the field of solar drying still had some room for improvement. In Malaysia with weather condition of hot and humid throughout the year it had a potential for development of high efficiency solar dryer. Manipulating the abundant energy from the sun for the purpose of drying with less cost involve for constructing is somehow favorable.

It is not that open sun drying method contributing to unhealthy emission or harming the environment but it is much more pleasant to implement and manipulating clean energy sources such as the energy from the sun to help with daily working condition. If industry applying the concept implement in this case study provided with several alteration to suite accordingly to their weather data and location they might be able to speed up the drying process by saving more space and increasing the number of agricultural product to be dried comparing to only relying on open sun drying.

In term of economic, the development of natural convection mode of solar dryer for this case study aiming to be low cost and performed as nearly efficient as other costly solar dryer available in market. Besides that, the research study will provide information on the issues of implementing the free energy resources to the fullest to replace traditional method of open sun drying with low cost possible.

In addition, this study would also review on the previous research conducted under the same field with variety of general idea from different part of the world having geographical and meteorology differences. Furthermore, this study would be beneficial to the industry and