A STUDY OF DRYING CHAMBER INTEGRATED WITH SOLAR COLLECTOR USING COMPUTATIONAL FLUID DYNAMICS

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**A report is submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering**

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2020

DECLARATION

I declare that this project report entitled "A study of drying chamber integrated with solar collector using Computational Fluid Dynamics" is the result of my own work except as cited in the references.

Signature	:	____________
Name	:	WONG SHIN FHUI
Date	:	26 JUNE 2020

APPROVAL

I hereby declare that I have read this project and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature	:	
Supervisor's Name	:	DR MOHD AFZANIZAM BIN MOHD ROSLI
Date	:	26 JUNE 2020

DEDICATION

To my beloved mother and father for the endless support.

ABSTRACT

Drying chamber integrated with solar collector has been introduced as one of the new advanced technologies and environment friendly process for drying agriculture products. To propose a proper drying chamber integrated with solar collector for specific products, uniform distribution of velocity and temperature in the chamber need to be considered. Computational Fluid Dynamics (CFD) Ansys Fluent 16.0 software is used to study and analyse the air flow and temperature distribution pattern within the drying chamber in order to reduce experimental time and avoid high cost. A validation results of a journal studying indirect solar food dryer is carried out using CFD. The validation is done by comparing the data experiment from the study journal with the data obtained from the CFD simulation. The results show that the maximum mean temperature difference on the symmetry plane of solar drier between the CFD Simulation in study journal and CFD validation is found to be 2.3 K. The CFD simulation shows high agreement with the results in study journal which shows that the CFD simulation's setting are correct and acceptable. With the purpose of improve the uniformity of airflow and temperature distribution in the drying chamber integrated with solar collector, three parameters are evaluated in this research which improve the weakness of the solar collector integrated drying chamber in the journal studied. The purpose of this study project is to investigate the performance of velocity and temperature distribution in drying chamber integrated with solar collector using three-dimensional (3D) CFD simulation in transient state condition. It was found that Parameter 3 (b) shows more uniform air flow velocity and temperature distribution with mean velocity 0.08m/s and mean temperature distribution 320.4K as compared to others design.

ABSTRAK

Ruang pengering yang disatukan dengan pengumpul suria telah diperkenalkan sebagai salah satu teknologi canggih dan proses mesra alam baru untuk pengeringan produk pertanian. Untuk mengusulkan ruang pengeringan yang tepat yang disatukan dengan pengumpul suria untuk produk tertentu, pengagihan kecepatan dan suhu yang seragam di dalam ruang perlu dipertimbangkan. Perisian Perkomputeran Dinamik Bendalir (CFD) Ansys Fluent 16.0 digunakan untuk mengkaji dan menganalisis aliran udara dan corak taburan suhu di dalam ruang pengeringan untuk mengurangkan masa eksperimen dan mengelakkan kos yang tinggi. Hasil pengesahan jurnal yang mengkaji pengering makanan suria tidak langsung dilakukan menggunakan CFD. Pengesahan dilakukan dengan membandingkan eksperimen data dari jurnal kajian dengan data yang diperoleh dari simulasi CFD. Hasil kajian menunjukkan bahawa perbezaan suhu maksimum pada satah simetri suria kering antara Simulasi CFD dalam jurnal kajian dan pengesahan CFD didapati 2.3 K. Simulasi CFD menunjukkan persetujuan yang tinggi dengan hasil dalam jurnal kajian yang menunjukkan bahawa CFD tetapan simulasi betul dan boleh diterima. Dengan tujuan meningkatkan keseragaman aliran udara dan pengedaran suhu di ruang pengering yang disatukan dengan pemungut suria, tiga parameter dinilai dalam penyelidikan ini yang memperbaiki kelemahan ruang pengering terpadu pengumpul suria dalam jurnal yang dikaji. Tujuan projek kajian ini adalah untuk mengkaji prestasi penyaluran halaju dan suhu di ruang pengeringan yang disatukan dengan pengumpul suria menggunakan simulasi CFD tiga dimensi (3D) dalam keadaan sementara. Didapati bahawa Reka Bentuk 3 (b) menunjukkan halaju aliran udara dan taburan suhu yang lebih seragam dengan halaju min 0.08m / s dan taburan suhu rata-rata 320.4K berbanding dengan reka bentuk yang lain.

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LIST OF ABBEREVATIONS

2 D	2-Dimensional
3 D	3-Dimensional
ANSYS	Analysis System
CAD	Computer-Aided Design
CFD	Computational Fluid Dynamics
CFX	Computational Fluid Xerography
ETSC	Evacuated Tube Solar Collectors
LPG	Liquefied Petroleum Gas or Liquid Petroleum Gas
UV	Ultraviolet

LIST OF SYMBOLS

C	Concentration of Water within the Material
Cp	Specific Heat Capacity
D	Diffusion Coefficient of the Material
E	Total Enthalpy
$\vec{F}$	Momentum Sink Term
g	Gravity
k_{eff}	Effective Conductivity
p	Pressure
ρ	Density
S_h	Volumetric Heat Source
t	Time
v	Flow Velocity/ Drying Time
$\vec{\tau}$	Stress Tensor
ρ	Concentration of Water within the Material

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Drying is a widely used process in industrial area to reduce moisture or removing water from a product or material, with a consequent weight reduction by evaporating from the product (Oluwasanmi and Obayopo, 2019; Al-Busoul, M. 2017). There are various sources that can supplied for food drying process, which is fossil fuel, natural gas and solar. Nowadays, due to certain reasons such as speedy exhaustion of natural fuel resources, environmental damages and increasing fossil fuel costs, solar energy is being given much attention in food drying process (Misha et al. 2019 and Demissie et al., 2019). This is because solar energy is abundant available and renewable around the world (Al-Neama et al., 2018). Drying process is important in industrial process in order to preserves the foods for longer period (Al-Busoul, M. 2017 and Al-Neama et al., 2018). It uses to dry various food products, for instance fruits, vegetables, meats, and fishes (Al-Busoul, M. 2017). Free excess water will cause the food materials corrupt if there is no drying process. Therefore, drying process plays an important role to removing the free water from food or agricultural products so as to extend shelf life of food, make them easier for packing, retailing and transport (Iranmanesh et al., 2019).

Open sun drying is considered as a traditional method of drying that had practice widely around the world. Open sun drying dries foods directly under the sun where exposed to the open air without any shielding or cover. This will eventually lead to low hygiene level of the dried product (Iranmanesh et al., 2019). Solar drying also facing some natural limitation such as rainy weather, winds, moisture and dusts that will fail or interrupting the drying process (Alqadhi et al., 2017) Also, the food products may be contaminated by dust, pollutant, rodents, insects or other animals. Thus, the drying process should be done in closed systems which provided shielding and covers to the food products, in order to maintain its best quality and hygiene (Al-Neama et al., 2018). In the early 1980s, high power, electrical dryers were introduced to the market (Gavelin, 1982). The purpose of drying chamber is to supply the heat to foods by convection and conduction from the surrounding air more than that available under ambient conditions at temperatures above the foods, or conduction from heated surfaces in contact with the foods in a closed system (Aissa et al., 2014). Electrical drying chamber has brought a lot of advantages to industry instead of using open sun drying process as it can cover the food from being polluted during the drying process. However, various electrical drying chamber in the industries also have some limitations such as those drying systems in the market require the use of electricity to motorize fan or pump in the drying chamber. Thus, it will increase the consumption of energy and also increase the cost on electricity. Nowadays, the device of drying chamber integrated with solar collector has been designed to conquer the disadvantage of traditional open sun drying and also the electrical drying chamber.

Drying chamber integrated with solar collector is a device that absorbs the incoming solar radiation, converts it into heat and transfer the heat to fluid such as air, water or oil flowing through the solar collector (Kalagirou, 2014). There are many advantages of using drying chamber integrated with solar collector such as fastening the drying speed due to the possibility of continuous batch operation (Abdullah et al.2020 and Dina et al.2015). As the food is in a separate and covered chamber, foods can be protected from animals, insects, and insect larvae. Thus, it has better dried product quality and hygiene due to controlled drying environment (Sotocinal, 1992). In addition, the food is not subject to direct radiation that can be harmful to some foods, particularly those that are UV-sensitive. The low capital and utility costs make solar drying attractive in poorer countries (Kerr, 2013). Besides that, drying chamber integrated with solar collector was operated in two drying modes, which is daytime and night time. In the daytime, the foods are dried inside the drying chamber by using hot air flow from the solar collector. At the same time, the solar collector is heated using direct solar energy in order to store the heat and release the moisture. Whereas at the night time, the solar collector is placed inside the drying chamber along with foods and the drying chamber was isolated from the ambient air. Thus, the drying process will be continued, although the temperature is relatively low. The meaning of continuous term here is that during sunshine hours and off-sunshine hours which is rainy day and also night time, the drying process is uninterrupted (Dina et al., 2015).

The main components in the solar collector integrated drying chamber including solar flat plat air collector, drying chamber, drying trays, centrifugal type blower, chimney, inlet, and outlet as shown in Figure 1.1.

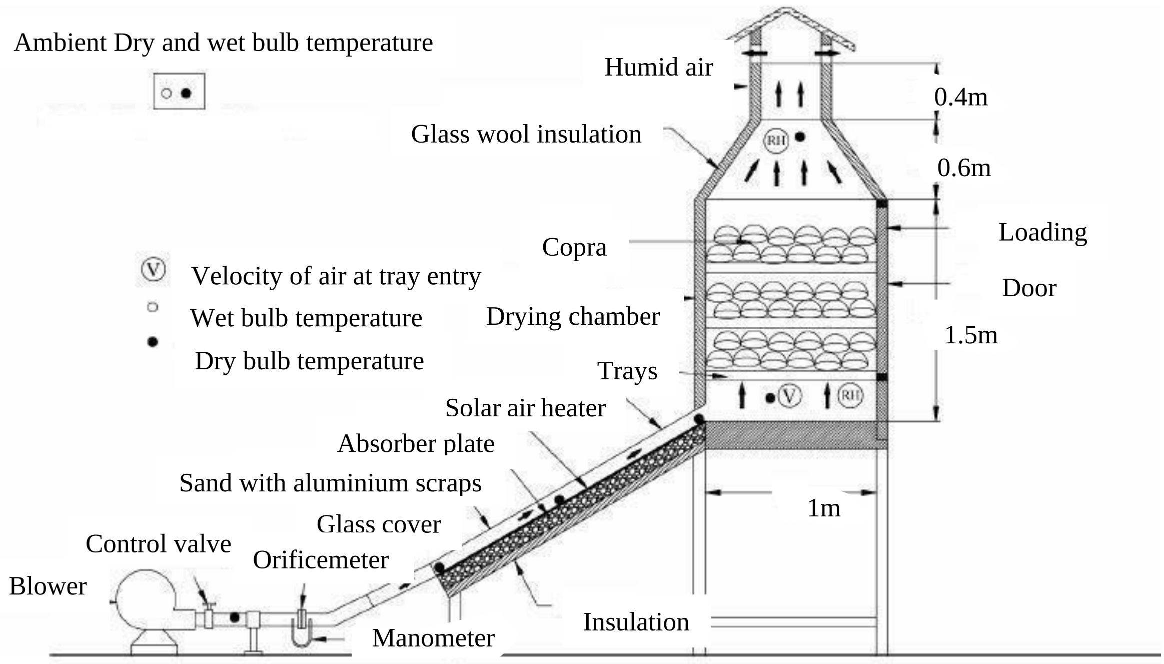

Figure 1.1 Indirect active solar dryer (Al-Neama and Farkas 2018).

In solar dryers, the radiant energy from sun penetrates on a glass cover and is collected on flat plate air collector, which heats air moving pass through it as shown in Figure 1.1. Air moves in by natural convection or may force in by blower or powered fan. (Kerr, 2013). When heat is added, the drying rate will increases based on the selected air velocity and drying temperature (Jayas and Sohkansanj, 1989). The function of a chimney is used to control the residency period of drying air in the drying chamber, increase overall efficiency of the dryer and maintain the optimum temperature inside the chamber with a better circulation of air. This component in drying chamber can prevent the excessive increase of temperature inside the chamber and adverse effects on the quality of the dried product (Aissa et al., 2014). Generally, the drying rate for solar collector drying chamber will be faster than direct sun drying (Kerr, 2013).

However, there are some problems that may encounter by using drying chamber, the problems are over drying and quick drying of food. Over drying on food will cause increase in energy value or cost. Fast drying will prevent the chemical processes started throughout the fermentation to be completed and thus reduces the dry matter of food (Arinze et al., 1996; Ndukwu, 2009). Therefore, correct prediction of the drying time is incredibly vital. Drying rate and drying consistent have the strong relationship with the drying temperature and air velocity. This is incredibly vital as these are the factors that lead to the good drying rate process (Ndukwu, 2009).

Computational fluid dynamics (CFD) is known as a of fluid mechanics that use numerical analysis and algorithm to solve and analyze the problem that involve fluid flows. CFD provides a qualitative and sometimes even quantitative prediction of fluid flows by means of mathematical modeling, numerical methods and also software tools (Ambesange and Kusekar, 2017). Recently, it has been used in multitudes of food drying applications, because of its promising design and modeling tool as a substitute to pricey experimental trials. The technique is successfully utilizing in predicting distribution of air flow and temperature distribution within drying chambers. It is also used to predict drying uniformity of a new design of the commercial tray dryer for agricultural products by analyzing temperature and velocity distribution. The usefulness of CFD for performance assessment of food processing applications is highlighted by predicting the air velocity field for drying chamber (Demissie et al., 2018).

The CFD simulations consist two method either steady or transient state as shown in Figure 1.2. From an initial condition, the simulation goes through an early stage which is transient state, and finally reaches the steady state regime. Owing to the fact of flow instabilities, the risers cannot consider in the real steady state conditions (Christian and Fernando, 2009).

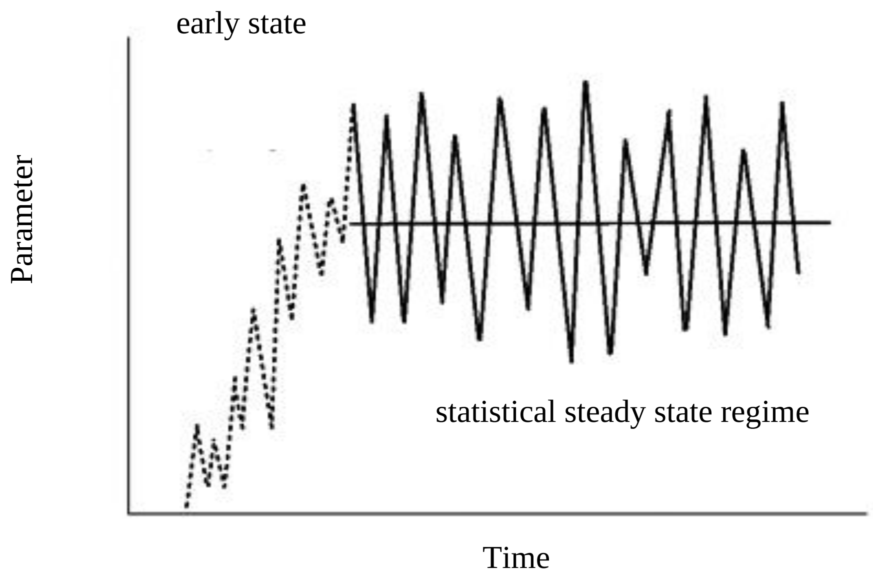

Figure 1.2: Behaviour of any parameter as predicted from a two-fluid transient simulation (Christian and Fernando, 2009)

The transient state is basically between the beginning of the event and the steady state. It refers to a process, which variables are changing in a particular time period. Basically, the transient period is a processed duration which shows unstable changes in variable, which also known as unsteady state (Chegg.com, 2009). However, steady state is the state that