HEAT FLOW ANALYSIS ON DOUBLE PASS SOLAR AIR COLLECTOR USING CFD

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**A thesis submitted
in fulfilment of the requirements for the degree of
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DECLARATION

I declare that this Choose an item. entitled "Heat Flow Analysis On Double Pass Solar Air Collector Using CFD" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Muhammad Fakhrullah bin Anis

Date : 25 JANUARY 2022

APPROVAL

I hereby declare that I have checked this thesis and, in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours.

Signature :

Supervisor Name : Nor Faizah Binti Haminudin

Date : 25 JANUARY 2022

DEDICATION

I dedicate this report to my parents Encik Anis bin Tahir and Puan Zainab binti Ali and my beloved supervisor Puan Nor Faizah binti Haminudin because self-efforts for the challenging work need from the elders. Not forget to my friends who have lending their hand to help me.

ABSTRACT

The solar drying of food industries products is considered the most excellent green and sustainable food industries product conservation method. The advancement of effective drying system design and food industries products drying characteristics will increase product conservation. The purpose of this study is to analyse a solar collector whose function is to transform solar radiation into heat and transfer that heat to the air. In this project, it is designed for the solar dryer to heat air that is used to remove moisture from the product placed inside the enclosure. The current research work focuses on the investigation analysis of solar collectors after some improvement of the design has been made. Double pass solar air collector with longitudinal fin in the second air passage is one of the important and attractive design improvements that has been proposed to improve the thermal performance. The entire solar collector is made of stainless steel, while the top cover is made of glass and the insulation is made of foam. ANSYS Fluent is used in simulations to numerically solve heat transfer, radiation, and fluid flow equations. Critical parameters such as outlet air temperature, outlet air velocity, and mass flow rate are evaluated along with absorber plate temperatures. Airflow over a smooth surface examined in geometry is assumed to be frictionless, and the ambient temperature is assumed to be constant. Material properties like density, thermal conductivity, and specific heat are assigned for materials stainless steel and glass. The simulation was done with air mass flow rates of 0.04 kg/s and 0.05 kg/s. Computational Fluid Dynamics (CFD) is used to theoretically test this double-pass solar collector. The CFD results obtained demonstrate a strong and positive correlation. The literature is used to verify all of the findings. The simulation reveals that this collector design has a good performance and is more efficient than single-pass collector models. An in-depth examination of the findings showed various design flaws, such as recirculation streams and the source of the problem, which will aid us in assessing and optimizing designs in future works.

ABSTRAK

Pengeringan solar produk industri makanan dianggap sebagai kaedah pemuliharaan produk industri makanan hijau dan mampan yang paling baik. Kemajuan reka bentuk sistem pengeringan yang berkesan dan ciri pengeringan produk industri makanan akan meningkatkan pemuliharaan produk. Tujuan kajian ini adalah untuk menganalisis pengumpul suria yang berfungsi untuk mengubah sinaran suria kepada haba dan memindahkan haba tersebut ke udara. Dalam projek ini, ia direka untuk pengering suria untuk memanaskan udara yang digunakan untuk mengeluarkan lembapan daripada produk yang diletakkan di dalam kepungan. Kerja penyelidikan semasa memberi tumpuan kepada analisis penyiasatan pengumpul suria selepas beberapa penambahbaikan reka bentuk telah dibuat. Pengumpul udara solar ganda lulus dengan sirip membujur di laluan udara kedua adalah salah satu penambahbaikan reka bentuk yang penting dan menarik yang telah dicadangkan untuk meningkatkan prestasi terma. Seluruh pengumpul suria diperbuat daripada keluli tahan karat, manakala penutup atas diperbuat daripada kaca dan penebat diperbuat daripada buih. Simulasi menggunakan ANSYS Fluent untuk menyelesaikan persamaan pengangkutan haba, sinaran dan aliran bendalir secara berangka. Parameter kritikal seperti suhu udara keluar, halaju udara keluar, dan kadar aliran jisim dinilai bersama dengan suhu plat penyerap. Aliran udara di atas permukaan licin yang diperiksa dalam geometri diandaikan tanpa geseran, dan suhu ambien diandaikan malar. Sifat bahan seperti ketumpatan, kekonduksian terma dan haba tentu diberikan untuk bahan keluli tahan karat dan kaca. Simulasi dilakukan dengan kadar aliran jisim udara 0.04 kg/s dan 0.05 kg/s. *'Computational Fluid Dynamics'* (CFD) digunakan untuk menguji pengumpul suria dua hala ini secara teori. Keputusan CFD yang diperoleh menunjukkan sekaitan yang kuat dan positif. Kajian ilmiah digunakan untuk mengesahkan semua penemuan. Simulasi mendedahkan bahawa reka bentuk pengumpul ini mempunyai prestasi yang baik dan lebih cekap daripada model pengumpul satu laluan. Pemeriksaan mendalam terhadap penemuan menunjukkan pelbagai kelemahan reka bentuk, seperti aliran edaran semula dan punca masalah, yang akan membantu kami menilai dan mengoptimumkan reka bentuk dalam kerja masa hadapan.

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Last but not least, from the bottom of my heart a gratitude to my beloved parents for their endless support, love and prayers. I would also like to thank all my friends who helped me a lot in finalizing this project within the limited time frame. I am really thankful to them. Finally, thank you to all the individuals who had provided me the assistance, support and inspiration to embark on my study.

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LIST OF SYMBOLS AND ABBREVIATIONS

D,d	-	Diameter
mm	-	Millimetre
mm^2	-	Square millimetre
mm^3	-	Cubic millimetre
cm	-	Centimetre
%	-	Percent
°C	-	Degree Celsius
kg/s	-	Kilograms per second
W/m K	-	Watts per meter-Kelvin
J/kg K	-	Joule per kelvin per kilogram
kg/m^3	-	Kilogram per cubic metre
T_i	-	Inlet temperature
T_o	-	Outlet temperatures
m	-	Fluid mass flow rate
Cp	-	Fluid's specific heat
T	-	Temperature
η	-	Efficiency of the collector
A_c	-	Collector area
S	-	Solar radiation
FR	-	Heat removal factor referring to inlet temperature
F_o	-	Heat removal factor referring to outlet temperature
UL	-	Collector total loss coefficient

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CHAPTER 1

INTRODUCTION

1.1 Background

Solar energy is the solar radiation capable of generating heat, initiating chemical reactions, and generating electricity. Solar energy incident on earth in total far exceeds the world's current and projected energy requirements. If harnessed properly, this highly diffused source of energy has the potential to meet all future energy needs. Solar energy is expected to become increasingly attractive as a renewable energy source in the twenty-first century, owing to its infinite supply and non-polluting nature, in contrast to the finite fossil fuels coal, petroleum, and natural gas.

Solar energy is a renewable and cost-effective source of energy. It has the potential to significantly reduce environmental pollution. Several applications using solar energy including heating purposes, electricity generation, and solar drying process. In this project, the focus of using solar energy on solar dryer is the main idea which the crucial part is the solar collector.

The current solar collector technology is used to collect the sun's radiation. The flat plate solar collector converts solar energy into beneficial heat gain, typically used to heat water and generate steam. Solar collector heat can be delivered directly to customers or stored. Steam can be used to power absorption chillers in air conditioning systems and can also be used to heat rooms directly. The collector's thermal performance is described in terms of thermal efficiency and fluid outlet temperature to meet energy demand.

The combination of the cover's high transmittance towards solar radiation and the receiver's high absorptivity results in excellent performance for a well-designed solar collector. Physical properties of the material, airflow rate, solar collector dimension, and solar irradiance are also important factors to consider when evaluating performance. This project predicts a flat plate solar collector's thermal efficiency and air temperature outlet based on parameters to be set.

1.2 Problem Statement

A solar collector is a device that captures and concentrates the sun's solar radiation. The solar collector is a critical component of a solar drying system. A simple solar air collector is composed of an absorber material, which may have a selective surface that absorbs solar radiation and transfers it to the surrounding air via convection heat transfer. This heated air is then ducted to the chamber or process area, where it is used to adsorb humidity of product which needed to be dried. Therefore, the drying process can be shortened and increase the quality of the product. However, solar air dryers are not widely used in Malaysia, and most Malaysians are unaware of their utility. Thus, this project will give insights into the use of solar energy by introducing the improvise version of flat plate solar collector in order to increase the solar thermal efficiency. The new design of solar collector consists of double-pass with longitudinal fins. This double pass was developed because a single pass was inefficient and required a larger solar collector dimension to increase the temperature further. By utilizing this double pass, it is possible to reduce the size of the solar collector by up to half while speeding up the heating of air. This solar collector is then analysed using CFD software to investigate the performances. The findings of the study will provide strong evidence in favour of the new solar collector design by examining the flow behaviour and temperature distribution on the solar collector.

1.3 Research Objectives

The primary objective of this research is to improve the solar collector so that it can produce more energy efficiently by means of adding fins and double pass air flow. Specifically, the objectives are as follows:

a) To conduct a stream line analysis of the current design of a solar collector using the ANSYS Fluent software.

b) To investigate the temperature distribution on the design of a solar collector.

c) To determine the thermal efficiency of a solar collector design using the ANSYS Fluent software.

1.4 Scope of Research

The scope of this research are as follows:

- The geometry of solar collector is 1200 mm x 1200 mm and the black painted plate with a dimension of 1095 mm x 1190 mm
- The solar collector is made of stainless steel, which does not taint food as a result of the heat process.
- It is assumed that there is no friction in the airflow over the surface and that the environment temperature remains constant.
- Finally, the thermal efficiency will be calculated.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Solar air collectors are commonly used in the heat process industry, solar water heating, space heating, solar desalination, and drying because they are practical and cost-effective. There are several alternatives to overcome the disadvantages of conventional solar air collectors in low thermal efficiency. Solar collectors come in a variety of designs that have been the focus of study and theory. The design of the solar collector needs to minimize the collector's heat loss, enabling even higher temperatures and a more efficient collector in the device phase. The flow rate has a significant impact on the collector's efficiency (Fudholi et al., 2011). A solar collector will operate better than a single pass solar collector if it has more passes by being equipped with heat-enhancing features such as fins and porous media. The coefficient of thermal transfer is an important parameter in the solar collector since it affects the thermal efficiency of the solar panel in terms of efficiently transferring heat from the absorber panel to the flowing air (Bakari, 2018). The main goal of this research is to investigate the mass flow rate, temperature distribution, and thermal efficiency that affectted the solar collector. Figure 2.1 depicts a solar collector with a double pass.

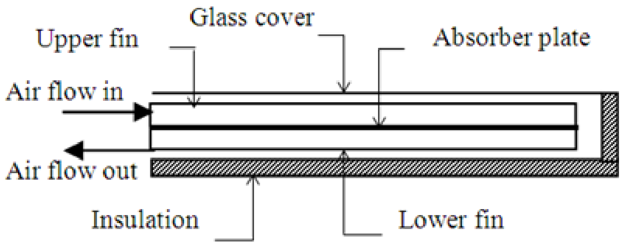

Figure 2.1 Schematic diagram of double-pass solar collector

2.2 Type of Solar Collector

In this sub-topic, various types of solar collectors used in previous studies are discussed. Solar collectors come in different shapes and sizes, but they all follow the same basic design principles. In general, some material absorbs and concentrates solar energy so that it can be used to heat water. The most basic of these systems consists of a black substance covering water-flowing tubing. The black body absorbs a significant amount of solar energy, and as it heats up, it also heated the surrounding water. While this is a simple design, collectors can become very complicated. If a high-temperature increase isn't needed, absorber plates may be used, but devices that use reflective materials to concentrate sunlight usually result in a higher temperature increase.

2.2.1 Concentrating Collectors

Solar concentrating collectors can produce higher temperatures than other collectors, such as flat collectors. There are two types of solar panels available, which are concentrated (tracking) and non-concentrated (non-tracking) collectors as shown in Figure 2.2. The concentrating collector has a surface that reflects a single point towards the receiver. The absorber has received a high amount of solar energy at a point that has been focused on from the collector and transferred to thermal energy for the following process (Gorjian et al., 2015). This type of solar collector will produce a higher temperature than those using a non-concentrating collector. Concentrating solar collectors operate well when used for absorption cooling applications.

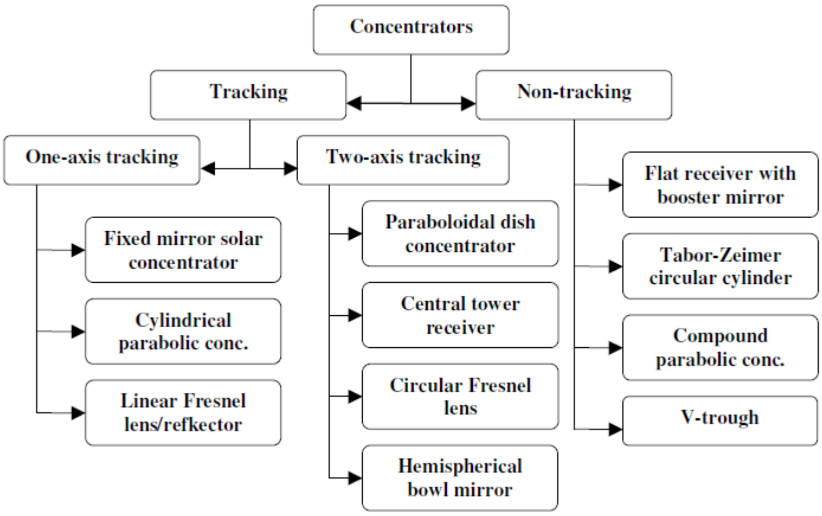

Figure 2.2 Classification of concentrators

2.2.2 Evacuated Tube Collector

Evacuated tube collectors differ from other collectors in terms of construction and the way they operate. This collector is created from many glass tubes made of annealed glass inside each of the inflatables as shown in Figure 2.3. Inside each of these inflatables has a collector plate. Vacuums are created in blown glass to reduce heat loss during conduction and convection during the manufacturing process. The evacuation process produces a vacuum that acts as an insulator and prevents shortwaves from escaping causing solar radiation to be trapped more effectively (Arora et al., 2011). Radiation is the only remaining cause of heat loss. High temperatures can be achieved because the absence of air in the tube can produce good insulation. Figure 2.4 shows the detail classification of evacuated collector.

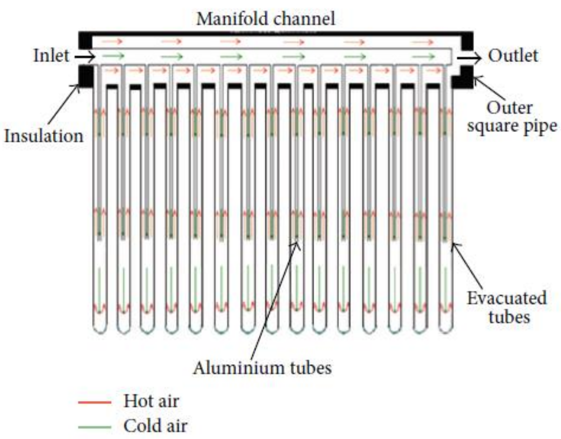

Figure 2.3 Solar air collector with evacuated tubes schematic diagram

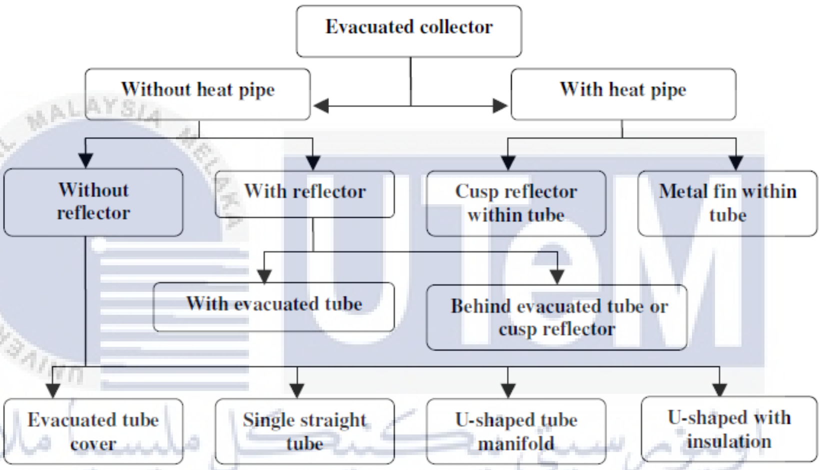

Figure 2.4 Classification of evacuated collector

2.2.3 Line Focus Collectors

Line focusing lenses are commonly used for low and medium concentration solar, photovoltaic or thermal systems, solar control of buildings and greenhouses, and solar heat collectors (Xie et al., 2013). The line focus collector collects and concentrates heat energy from sunlight using a highly reflective material. The reflective part of this collector is parabolic in shape and connected to a long trough. The sunlight collected by the reflective material will be reflected on the pipe placed in the middle of the trough and heat the pipe contents. Due to the high energy collectors, line-focused collectors are commonly used in solar power plants to produce steam and are not suitable for residential use. The generation of heat from the sun by the trough is very effective, especially the one that can rotate to detect the sun in the sky to maximize the accumulation of sunlight. The economic and flexible focus line has been widely used in various fields such as energy generation, solar heating and cooling, desalination, industrial processes, and solar fuel production (Sun et al., 2020). Figure 2.5 illustrates a straightforward diagram of how the majority of contraptions are planned to absorb solar energy.

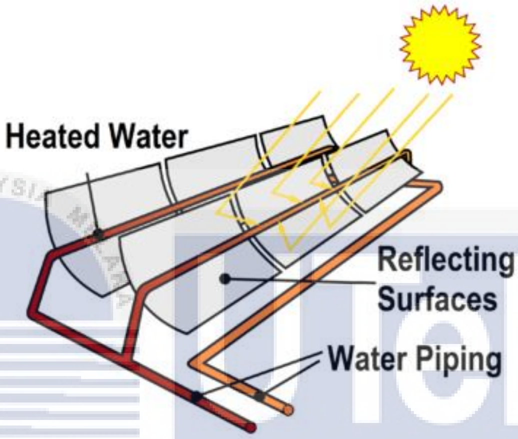

Figure 2.5 A line focus solar collector.

2.2.4 Flat-plate Collector

The most widely known type of solar collector is the flat-plate collector, which Hottel and Whillier invented in the 1950s. In low-demand areas, they are widely used for water heating and space heating. A flat plate collector is essentially a factor pointing in the direction of the sun. A flat plate collector is usually made up of an insulated metal box with a glass or plastic cover and a dark-coloured absorber plate. Copper, steel, or plastic are commonly used as absorber plates. A flat black material with a high absorptance is applied to the surface. If copper or steel is used, a selective coating may be applied to improve solar energy absorption while reducing the amount of radiation emitted by the plate. The working fluid is carried through the collector by the flow passages. The flow passage is