STUDY THE EFFECT OF FIN ON SOLAR COLLECTOR PERFORMANCE USING CFD SIMULATION

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DECLARATION

I declare that this project report, "Study the Effect of Fin on Solar Collector Performance Using CFD Simulation," is entirely my work, except for the references.

Signature: ……………………………………..
Name : EFFY RUSHDANE AFFANDI BIN HASNALEE
Date : 9/01/2022

APPROVAL

I hereby certify that I have reviewed this project report and believe it to be adequate in scope and quality for the award of the Bachelor of Mechanical Engineering degree.

Signature : ………………………………
Name of Supervisor : ………………………………
Date : ………………………………

DEDICATION

To my beloved parents, family and myself.

ABSTRAK

Secara amnya, pengumpul udara solar digunakan untuk menangkap tenaga haba untuk pengeringan. lazimnya, pengumpul udara solar tradisional termasuk penyerap untuk menangkap haba daripada sinaran matahari. Walau bagaimanapun, dalam keadaan tertentu, haba yang dikumpul oleh pengumpul udara solar tradisional adalah tidak mencukupi kerana beberapa faktor seperti iklim dan tujuan haba dikumpul. Prestasi pengumpul udara solar boleh dipertingkatkan dengan mengubah komponen yang digunakan untuk menyerap haba dengan menambah sirip pada penyerap pengumpul. Tujuan penyelidikan ini adalah untuk menentukan pengaruh sirip pada pengumpul suria. Objektif utama kerja ini adalah untuk membangunkan, memeriksa, dan menganalisis prestasi terma segi empat tepat, beralun, alur-v dan mendatar susunan sirip pengumpul suria menggunakan pengiraan dinamik bendalir secara komputasional (CFD). Tujuan simulasi CFD adalah untuk menentukan pengaruh sirip pada kenaikan suhu, tekanan, dan halaju aliran bendalir dalam pengumpul suria dengan mensimulasikan keadaan fizikal sesuatu kajian model pengumpul udara solar. Dapatan kajian menunjukkan bahawa sirip segi empat tepat, sirip beralun, sirip alur berbentuk v, dan sirip mendatar semuanya mempunyai kenaikan suhu yang lebih tinggi daripada model kajian, pada 5.4 peratus, 5.6 peratus, dan 5.3 peratus, masing-masing, manakala sirip mendatar mempunyai yang paling tinggi kenaikan suhu pada 5.7 peratus, berbanding model kajian 4.2 peratus. Kesimpulannya, kajian ini menyimpulkan bahawa sirip mendatar memberikan peningkatan haba yang terbaik, tetapi segi empat tepat sirip adalah pilihan yang lebih baik dalam keadaan dan aplikasi yang setanding dengan model kajian.

ABSTRACT

Typically, a solar air collector is used to capture thermal energy for drying. Typically, a traditional solar air collector includes an absorber to capture heat from the sun's rays. However, under certain circumstances, the heat gathered by a traditional solar air collector is insufficient due to considerations such as climate and the purpose of the collector. A solar collector's thermal performance can be enhanced by altering the material used to absorb heat, for as by adding fins to the collector's absorber. The purpose of this research is to determine the influence of fins on a solar collector. The primary objective of this work is to develop, examine, and analyze the thermal performance of rectangular, wavy, v-groove, and horizontal fins arrangement solar collectors using computational fluid dynamics (CFD). The purpose of the CFD simulation is to determine the influence of fins on temperature rise, pressure, and fluid flow velocity in the solar collector by simulating the boundary conditions of a study model solar air collector. The study's findings indicate that rectangular fins, wavy fins, v-groove fins, and horizontal fins all have a higher temperature rise than the study model, at 5.4 percent, 5.6 percent, and 5.3 percent, respectively, while horizontal fins have the highest temperature rise at 5.7 percent, compared to the study model's 4.2 percent. In conclusion, the study concluded that horizontal fins provide the best thermal improvement, but rectangular fins are a better choice in a comparable circumstance and application to the study model.

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CFD	Computational Fluid Dynamics
CAD	Computational Aided Design
b	Space between fins (mm)
V	Velocity of air between fins (m/s)
f_1	Friction factor
H_f	Fin height
k	Turbulent kinetic energy
K_f	Thermal conductivity of the fluid (W/mK)
L	Length of the fin (mm)
ṁ	Mass flow rate (kg/s)
Nu	Nusselt number
P	Pressure (Pa)
Q	Heat flux (W/*m*2)
μ	Dynamic viscosity (N s/*m*2)
ρ	Density (*kg/m*3)
ε	Rate of dissipation of turbulent kinetic energy
Re	Reynold Number
T_i	Inlet temperature of air (K)
T_o	Outlet temperature of air (K)

Chapter 1

INTRODUCTION

1.1 Background

The world's energy demand is increasing drastically as the growth of the Earth's population soars each year. As a result, the energy demand is also growing which also sparks economic development to increase significantly. As economic development takes place, the energy demand also increases following the economic growth trend. Using non-renewable energy will not meet the energy demand since it is limited. Moreover, the use of non-renewable energy sources leads to climate change which causes natural disasters that may be harmful to the ecosystem. Therefore, renewable or eco-friendly energy sources are the way to go for the greater good of the future. Solar energy could be the best choice as energy is the most abundant renewable energy source. (Kannan & Vakeesan, 2016).

Solar energy is openly has a lot of advantages relative to any other energy source. It does not use natural resources, no carbon dioxide or other gaseous emissions into the air, or produces wastes. The advantages of solar energy are the following:

- No greenhouse gases emissions
- Recover degraded land
- Improve the quality of water resources
- Increase energy independence

(Solangi et al., 2011).

Global warming, caused by CO_2 emissions, has become a serious issue that must be monitored as global energy consumption continues to expand. Solar energy, in particular, is widely regarded as a critical component of attaining sustainable human expansion and as one of the most effective cures for global warming. Solar collectors are a type of solar energy harvesting device. The solar collector is a one-of-a-kind energy exchanger that converts solar energy directly into thermal energy from the working fluid in photovoltaic applications or into electricity in solar thermal applications. Solar radiation is captured by a solar collector and converted to heat for solar thermal applications before being transferred to the collector's working fluid (air, water, or oil). The heat transferred by the working fluid can be utilised for domestic hot water/heating or can be used to charge a thermal power storage tank from which heat can be extracted later (at night or cloudy days). Numerous non-concentrated solar collectors, such as flat solar collectors, are available. A different sort of solar collector is the concentrating collector. (Tian & Zhao, 2013).

1.2 Problem Statement

A solar energy system should be designed in such a way that it produces the appropriate amount of energy at the lowest possible cost. A flat plate collector is one of the solar energies. A flat plate heat exchanger air collector is a form of heat exchanger that receives solar radiation and converts it to heat energy. Thermal efficiency is used in this method to compare the thermal performance of solar collectors. Thermal efficiency is widely thought to be the most critical criterion for thermal performance estimation. The typical solar air collector, on the other hand, is well-known for its poor thermal performance. The study refers to a model for conducting research. Under the absorber, this model employs a simple fin structure. To improve the thermal performance of the system, it is necessary to study, build, and assess an appropriate design strategy utilizing computational fluid dynamics (CFD).

1.3 Objective

This project aims to study the effect of fins on solar collectors. This report should accomplish the following objectives:

1. To study the effect of fins on solar collectors.
2. To design, study and analyse with CFD the rectangular, wavy, v-groove and horizontal fins configuration design of solar collectors in thermal performance.
3. To compare the effect of fins on temperature rise, pressure, and the velocity of air in the solar collector.
4. To choose the appropriate fin configuration design that are suitable to improve the current study model design.

1.4 Scope of Project

The scopes of this project are:

1. Only results of solar collector that is influenced by the existence of fins are presented in this report.
2. The CFD simulation of the effect of fins on the solar collector is analysed and validated by experimental results.
3. Apart from the plain fin from the study model, the rectangular, wavy, v-groove and horizontal fins will be newly designed.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

The literature review that will be used in this project will be covered in this chapter. The material will include information about solar collector systems with and without fins, fin comparisons between prior research investigations, and actual fin designs and simulation efforts.

2.2 Overview of Solar Collector System and fins

The solar collector is a critical component of a solar energy system. It is a device that collects solar energy, converts it to thermal energy, and then transfers the thermal energy to the fluid running through the collector. A flat-plate collector is a type of solar collector that is well-known. The simplest solar collector, with no glass and an uninsulated absorber plate. This collector is ideal for swimming pool heating applications where the water temperature needs to be raised merely a few degrees above the ambient air temperature (0–10 °C). As a result, heat losses are negligible. A glass or plastic cover may be used to reduce heat loss. A solar collector with glazing is composed of a cover, an absorber plate, and insulation on the bottom and sides. The cover may be used to prevent heat loss from the collector's top, and the absorber plate may be insulated to prevent heat loss from the collector's surroundings. A basic solar collector consists of a flat plate collector covered in glass and equipped with an air channel (single pass). Frequently, a black-painted absorber plate is used. In higher-temperature collectors, one or more glazing layers are commonly utilised. (Fudholi & Sopian, Review on Solar Collector for Agricultural Produce, 2018). A solar air heater is a device designed to meet present and future mild temperature requirements for space heating, agricultural product drying, and industrial processes. (Close, 1963). Solar collectors are frequently classified into two categories based on their concentration ratios: non-concentrating and concentrating collectors. (Tian & Zhao, 2013).

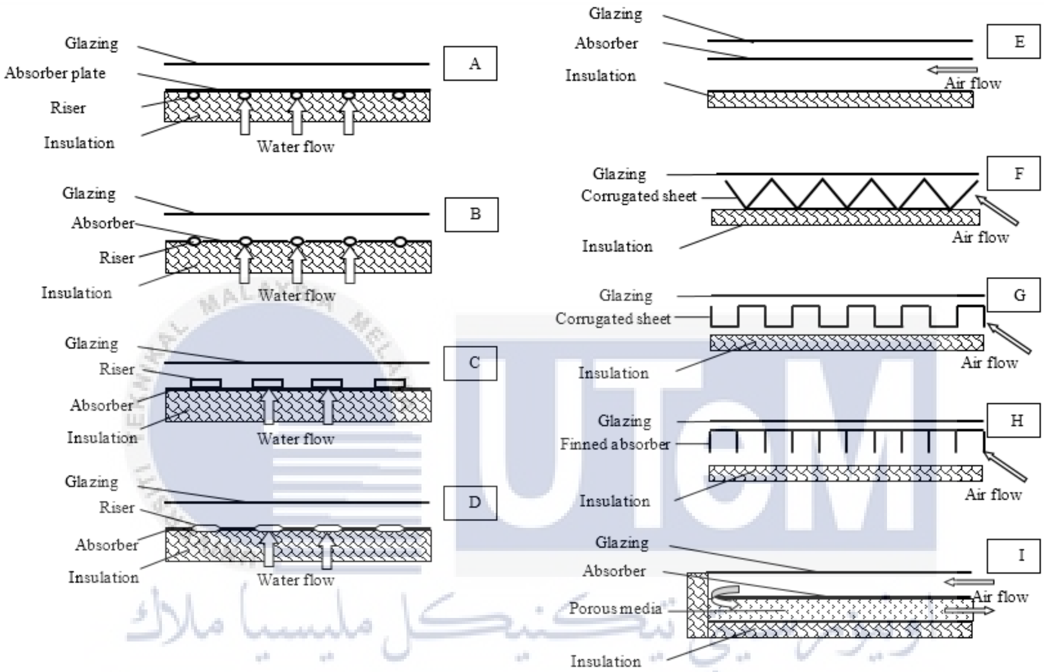

Figure. 2.1. Various Types of Flat-Plate Solar Collectors: A-D: Water-Based Solar Collectors, (Fudholi & Sopian, Review on Solar Collector for Agricultural Produce, 2018).

Figure 2.1. (E) depicts a standard flat-plate collector with a clear cover, absorber, insulation, and frame. As a result, a flat-plate collector is made up of one or more glass sheets or a transparent material placed atop an absorbent plate with air flowing around it. Traditional flat-plate collectors have low thermal efficiency. To achieve a significant collector efficiency increase, enlarged heat transfer regions, such as corrugated surfaces (Figures 2.1. (F) and 2.1

(G)), finned absorbers (Figure. 2.1 (H)), and porous media (Figure 2.1. (I)), are required. (Fudholi & Sopian, 2018).

Due to ongoing research in the field of solar air heaters, a variety of designs are now available. Researchers are primarily interested in accounting for thermal losses to the environment as well as the pumping power required to maintain the airflow rate in solar air heaters. The glass covers, as well as the absorber and back plates, are the key components of traditional solar air heaters. Traditional solar air heaters that use such components, however, have poor thermal performance. (Biondi, Cicala, & Farina, 1988). As a result, increasing the air circulation duration by Mohamad (1997), and increasing the heat transfer area by attaching surfaces to the absorber plate by Momin, Saini, & Solanki (2002), are two key options documented in the literature for improving the thermal performance of traditional solar air heater designs. However, for greater thermal performance, a double glass cover is also advised. (Ho, Lin, Chuang, & Chao, 2013).

The tunnel's working fluid is circulated and heated by the hot absorber plate. Controlling the enclosure material's heat transfer resistance to any particular working fluid flowing through the route is how heat transfer is regulated. Increasing the surface area of the enclosure is one way to reduce resistance. (Flynn, Akashige, & Theodore, 2019). This can be accomplished by providing a longer surface or adding extra material with varied geometries into the enclosure's route. The addition of a longer surface or substance, on the other hand, increases the pressure drop over the collector. (Akpinar & Koçyiğit, 2010). This was also presented by Singh Yadav & Kumar Thapak (2014), where the surface roughness enhances flow turbulence and hence heat transfer efficiency. The thermal-hydraulic performance of the roughness geometry ‘V-down rib with a gap' has been studied, and artificial roughness geometries utilized in solar air heater ducts have been reported. In comparison to a smooth duct, artificial roughness as an inherent element of the SAH module improves the thermoshydraulic performance of the system. (Singh, Chander, & & Saini , 2015). The roughness of the absorber plate increases the heat transfer coefficient by increasing the friction coefficient, according to the findings by Lingayat, Chandramohan, & Raju, (2018).

According to Vyas & Punjabi (2014), the thermal efficiency and temperature gradient of three different flat plate air collector designs (plane absorber, transverse V-porous ribs, and inclined V-porous ribs of absorber) were evaluated in an experimental setting using solar radiation and natural convection flow models. These three models had a total thermal performance of 14.91 percent, 17.24 percent, and 20.04 percent, respectively. Additionally, greater system productivities indicated a decrease in the temperature gradient.

Naphon (2005) calculated the thermal performance of a longitudinally finned absorber plate solar air heater with a single glass cover to be around 60% at mass flow rates ranging from 0.02 kg/s to 0.1 kg/s. Additionally, increasing the fin height and number of fins decreases the rate of entropy generation while increasing thermal efficiency. Kumar & Chand (2017) expected that the longitudinal herringbone corrugated ultrafine solar air heater will improve its thermal performance. According to the findings, thermal efficiency improves as mass flow rate, solar radiation, and fin pitch and spacing decrease. Singh & Dhiman (2016) used an analytical model to predict the thermal performance of a longitudinally finned solar air heater and show how mass flow rate, recycle ratio, number of fins, and collector width affect thermal performance. For five numbers of fins, the minimum width of the collector is 0.3 m, the recycle ratio is 1.5, and the mass flow rate is 0.025 kg/s, the maximum thermal efficiency is found to be around 82 percent.

Priyam & Chand (2016) shows the influence of fin spacing and mass flow rate on a wavy fined solar air heater. The offset staggered finned solar air heater's thermal and thermohydraulic efficiencies are expected by Rai, Chand, & & Sharma (2017). With a