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SESI PENGAJIAN: **2023-2024 Semester 1**

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EFFECTS OF FIN ARRANGEMENT ON THE AIR FLOW BEHAVIOUR IN DOUBLE PASS SOLAR COLLECTOR USING CFD

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY
(AUTOMOTIVE TECHNOLOGY) WITH HONOURS

2024

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical Technology and Engineering

EFFECTS OF FIN ARRANGEMENT ON THE AIR FLOW BEHAVIOUR IN DOUBLE PASS SOLAR COLLECTOR USING CFD

FARITH AIMAN BIN AMIRUDIN

Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours

2023

EFFECTS OF FIN ARRANGEMENT ON THE AIR FLOW BEHAVIOUR IN DOUBLE PASS SOLAR COLLECTOR USING CFD

FARITH AIMAN BIN AMIRUDIN

A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours

Faculty of Mechanical Technology and Engineering

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2024

DECLARATION

I declare that this Choose an item. entitled "Effects of fin arrangement on the air flow behaviour in double pass solar 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.

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Signature :
Supervisor Name : Puan Nor Faizah Binti Haminudin
Date : 19 JAN 2024

DEDICATION

I dedicate this report to my parents Encik Amirudin bin Abas and Latifah binti Daud 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 study focuses on sun drying machines that employ a mixed mode and a double-pass solar collector. There are challenges that must be solved and the collector's performance and efficiency must be improved in order to use sun drying for food preservation correctly. Hence, in order to design the best solar collector, research and analysis are conducted to examine the effects of various fin configurations on the behaviour of the airflow in a double-pass system. A better heat transfer efficiency and overall performance from the system is required. Uneven heating and worse performance might result from the lack of fins that distribute airflow. The purpose of the fins is to enhance the area available for heat transfer, which in turn allows for greater absorption of solar heat and increased air movement inside the collector.Thus, several fin arrangements, including straight, staggered, and pin fins, will be employed in this study. These arrangements will have an impact on how the airflow is distributed in the collector. Using SolidWorks, a solar collector with various fin arrangements has been designed. The top cover is composed of glass, while the solar collector is entirely constructed of stainless steel. The Ansys Fluent tool is used to execute the simulation. In order to maximise convective heat transfer within the collector, it is crucial to comprehend these airflow complexities. Material properties like density, thermal conductivity, and specificheat are assigned for materials stainless steel and glass. Critical parameters such as outlet air temperature, outlet air velocity, and mass flow rate are evaluated along with absorber plate temperatures. In this research, Ansys simulations will be used to track the thermal efficiency of the solar collector by consider the stream line, velocity and pressurel in the solar collector system. The dynamics of airflow in a double-pass solar collector with different fin designs are investigated in this work. Subtle effects are shown by the velocity profiles: straight fins achieve a maximum velocity of 17.57 m/s, pin fins reach 9.84 m/s by increasing the surface area, and staggered fins reach 24.40 m/s because they are offset. In order to maximise convective heat transfer within the collector, it is crucial to comprehend these airflow complexities.

ABSTRAK

Kajian ini memfokuskan kepada pengering suria yang menggunakan pengumpul suria dwi laluan campuran. Beberapa cabaran perlu ditangani dan kecekapan dan keberkesanan penuai perlu dipertingkatkan untuk menggunakan pengeringan matahari dengan sewajarnya untuk pengawetan makanan. Oleh itu, untuk mereka bentuk pengumpul suria yang terbaik, penyelidikan dan analisis telah dijalankan untuk mengkaji kesan konfigurasi sirip yang berbeza terhadap tingkah laku aliran udara dalam sistem aliran dwi. Prestasi pemindahan haba yang lebih baikdan prestasi sistem keseluruhan yang lebih baik diperlukan. Disebabkan kekurangan sirip untuk mengagihkan aliran udara, pemanasan yang tidak sekata dan prestasi yang lemah boleh berlaku.Tujuan sirip adalah untuk meningkatkan kawasan yang tersedia untuk pemindahan haba, yang seterusnya membolehkan penyerapan haba matahari yang lebih besar dan pergerakan udara yang lebih besar dalam pengumpul. Oleh itu, pelbagai susunan sirip digunakan dalam kajian ini, antaranya sirip lurus, bersusun, dan berbentuk pin. Peraturan ini mempengaruhi cara pengaliran udara diedarkan dalam manifold. Pengumpul suria dengan pelbagai susunan sirip direka menggunakan SolidWorks.Penutup atas diperbuat daripada kaca, manakala pengumpul suria dibuat sepenuhnya daripada keluli tahan karat.Alat Ansys Fluent digunakan untuk menjalankan simulasi. Untuk memaksimumkan pemindahan haba perolakan dalam pengumpul, adalah penting untuk memahami kerumitan aliran udara ini. Bahan keluli tahan karat dan kaca diberi sifat bahan seperti ketumpatan, kekonduksian terma dan haba tentu. Parameter penting seperti suhu udara ekzos, halaju udara ekzos dan aliran jisim dinilai bersama-sama dengan suhu plat penyerap. Dalam penyelidikan ini, simulasi Ansys digunakan untuk mengesan kecekapan terma pengumpul suria dengan mengambil kira aliran, halaju dan tekanan dalam sistem pengumpul suria.Kajian ini menyiasat dinamik aliran udara dalam pengumpul suria dua hala dengan reka bentuk sirip yang berbeza. Profil kelajuan menunjukkan kesan halus: sirip lurus mencapai kelajuan maksimum 17.57 m/s, sirip pin mencapai 9.84 m/s apabila luas permukaan bertambah, dan sirip bertindan mencapai 24.40 m/s disebabkan oleh geseran yang ada.Untuk memaksimumkan pemindahan haba perolakan dalam pengumpul, adalah penting untuk memahami kerumitan aliran udara ini.

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LIST OF SYMBOLS AND ABBREVIATIONS

D,d - Diameter
R,r - Radius
mm - Millimetre
mm^2 - Square millimetre
mm^3 - Cubic millimetre
cm - Centimetre
% - Percent
°C - Degree Celsius

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Solar energy is the term for the solar radiation that causes heat, ignites chemical processes, and generates electricity. The amount of solar energy incident on Earth is much more than the world's projected and current energy requirements. If correctly used, this widely dispersed energy source might meet all future energy needs. Solar energy is anticipated to surpass the limited fossil fuels such as coal, petroleum, and natural gas in popularity among renewable energy sources in the twenty-first century due to its infinite supply and absence of pollution.. Figure 1.1 shows solar energy generate electricity.

Figure 1.1 Solar energy generated into electricity.

Solar energy is a renewable, and cost-effective energy source. It can significantly reduce pollution in the environment. Solar energy can also be used to heat buildings by solar thermal systems. These systems collect solar energy and use it to heat water or air for a variety of uses such as room heating, water heating, and even powering cooling systems. The fundamental idea of this research is to use solar energy on a solar dryer, with the solar collector being the most important component.

A solar collector is a device that gathers and focuses the sun's solar energy. This device uses heating air to dry goods. These solar collectors are designed to gather sunlight and transmit heat to a medium such as air or water. A solar collector can be used to heat the air which is then circulated around the food to adsorb moisture from the food and help to dry in the context of drying food. This method is often employed in solar food dryers, which are equipment developed expressly for drying fruits, vegetables, herbs, and other food products. There are various advantages of using a solar dryer for food drying. It makes use of solar energy, reducing dependence on traditional energy sources. It can save money in the long term because it uses free solar energy. Furthermore, as compared to other drying processes, solar drying can help retain the nutritional value of the food and enhance its flavour. So, it should be remembered that the effectiveness of solar drying depends on various factors such as the design, fin arrangement, size of the solar collector, weather conditions, and the type of food being dried. Figure 1.2 shows an example of solar collector dryer food.

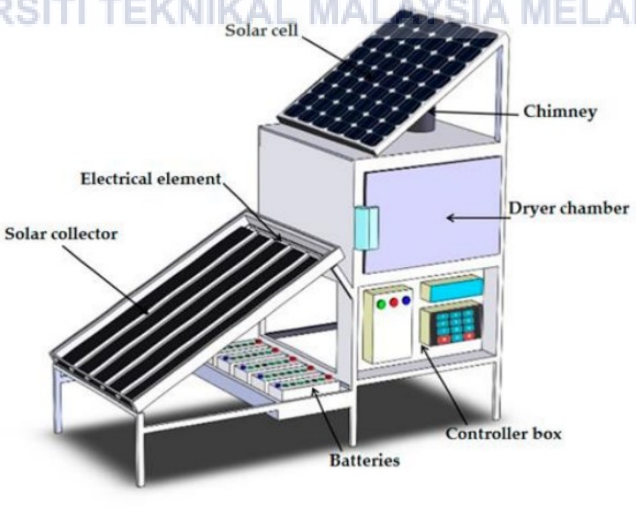

Figure 1.2 Solar collector dryer food

1.2 Problem Statement

In this study, a double-pass solar collector is utilised for a mixed mode solar dryer machine. There are challenges encountered, and requirement to optimize the use of sun drying for food preservation by improving the collector's performance and efficiency. Moreover, the configuration of fins in the double-pass solar collector significantly influences the airflow behavior, thereby impacting the quality of the solar collector. Hence, to achieve the best solar collector, an investigation and analysis are focused to examine the effects of various fin arrangements on the airflow behavior in a double-pass solar collector system. The aim is to improve the system's heat transfer efficiency and overall performance.

The addition of fins in a double-pass solar collector addresses the issue of inefficient heat transfer within the system. Without fins, the airflow may not be properly distributed, leading to uneven heating and reduced overall performance. The fins serve the purpose of increasing the surface area available for heat transfer, allowing for better heat absorption from the sunlight and improved convection of air within the collector. This helps to increase heat transfer efficiency and ultimately maximise the effectiveness of the solar drying process. Thus, different types of fin arrangement will be used in this research which is straight fins, staggered fins, and pin fins, which will affect the airflow distribution in the collector.

1.3 Research Objective

The main purpose of this research is to enhance the double-pass solar collector by embedding different types of fins so that it can produce energy more efficiently. The following are the objectives:

a) To investigate different types of fin arrangement on double-pass solar collector.

b) To conduct airflow behavior effect on the fin arrangement on double-pass solar collector.

1.4 Scope of Research

The scope of this research is as follows:

- The geometry of the solar collector is 1200 mm x 1200 mm, the black painted flat plate with a dimension of 1745 mm x 1190 mm and 5 mm thickness of the glass plate.
- The material used is stainless steel to prevent food from becoming tainted during the heating process.
- The types of fin arrangement are straight fins, staggered fins, and pin fins.
- The distribution of temperatures will impact by the airflow behavior across the fin arrangement.
- The pressure distribution analysis that will occur by the airflow over the fin arrangement is studied.
- The solar collector will be simulated by using Computational Fluid Dynamics (CFD) software which is Ansys Fluent.
- It is assumed that there is no friction in the airflow over the surface and that the environment temperature remains constant.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Solar air collectors are widely utilised in the heat process industry, solar water heating, space heating, solar desalination, and solar drying due to their practicality and affordability. There are a number of alternatives to conventional solar air collectors that address the issue of insufficient thermal efficacy. There are numerous designs for solar collectors that have been the subject of research and conjecture. The solar collectors' heat can be delivered directly or stored. To meet the energy demand, the thermal performance of the collector is measured in terms of thermal efficiency and fluid temperature at the discharge. Experimental and theoretical investigation of the impact of solar air collector fin connection on parameters of operation and thermal efficiency was conducted. Ali Daliran et al. (2018) have documented the investigation and comparison of discharge air temperature variation. It has been discovered that a solar collector operates more efficiently if it is outfitted with heat-enhancing features such as fins and porous media and has more passages. In addition, the coefficient of thermal transfer is essential in the solar collector because it influences the thermal effiecancy of in terms of effectively transmitting heat from the absorber panel to the moving air, the solar panel (Bakari, 2018). The primary purpose of this research is to determine the connection between mass flow rate, temperature distribution, and thermal effects on the solar collector.

2.2 Type of solar collector

This topic discusses numerous types of solar collectors utilised in prior investigations. Solar collectors exist in a variety of forms and sizes, but they always keep to the same basic rules of design. These devices help to lower energy use over time. Solar collectors are useful not just for conserving energy in homes, but also on a business scale. There are several types of solar collectors available for harnessing solar energy. The fundamental concept of a solar air collector revolves around the utilisation of sunlight to generate thermal energy. This collector comprises a dark-colored surface, commonly made of metal or a material with excellent thermal conductivity. Positioned in direct sunlight, this surface absorbs solar radiation and transforms it into heat. Behind the heat-absorbing surface, there is usually an air channel or duct. As the absorbed solar energy heats up the surface, the adjacent air also gets warmed. The hot air rises and flows into the duct, creating a natural convection or forced airflow system. While this is a simple design, yet collectors may get rather complex. Absorber plates can be utilised if a large temperature increase is not required, although systems that use reflective materials to focus sunlight generally result in a higher temperature increment. Hence, various type of solar collectors has been produced such as concentrating collectors, flat-plate collector, evacuated tube collector, line focus collectors and many more as describes in the next sub-sections.

2.2.1 Concentrating solar collector

Solar concentrating collectors could generate greater temperatures than other types of collectors, such as flat collectors. A linear focus secondary trough concentrating system concept that tackles the limitations of the traditional parabolic trough system. It highlights the benefits of eliminating end losses and connecting concerns, boosting the concentration ratio, presenting a thorough design plan, and emphasising its potential as a solar energy experimental device. The innovative design enables the aperture to be enlarged, giving the ability to improve the concentration ratio. Higher concentration ratios can result in higher temperatures and overall system efficiency (Xiliang Zhang, 2018). Another type of concentrating collector is a solar power tower. The solar tower has the benefit of allowing the reflectors to be modified rather than the entire tower. Power tower technology is less advanced than trough systems.

However, they are more efficient and have a greater capacity for energy storage. Next, the type of concentrating collector is Fresnel reflector as shown in Figure 2.1. This device contains several thin, flat mirror strips that are used to focus sunlight on tubes through which working fluid is poured (Sumit Chakrabarti, 2022).

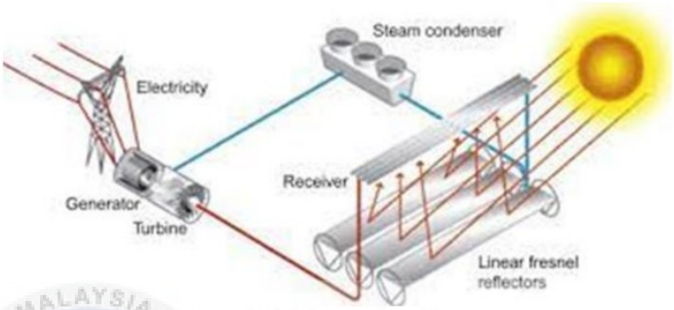

Figure 2.1 Fresnel reflectors.

One example of concentrating collector is parabolic trough collector, these collectors are made of curved, parabolic-shaped mirrors that focus sunlight onto a linear receiver tube situated at the parabola's focal line. A heat transfer fluid, such as oil or molten salt, is contained in the receiver tube and absorbs the concentrated sunlight before transferring the heat to a power cycle or heat exchanger (Mohammad Abdul Baseer, 2018). Figure 2.2 shows a parabolic trough collector cut in half.. The absorber tube is formed of a metal tube covered in a glass envelope. To allow for expansion in temperature and to prevent convective heat losses, the gap between the outer layer of glass and a metal tube is filled with air, or vacuum.

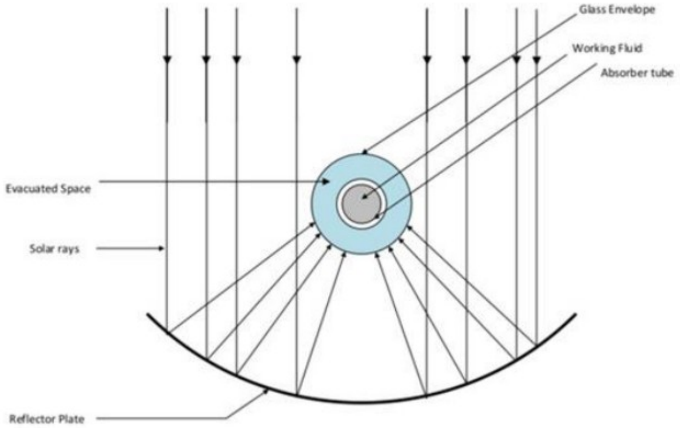

Figure 2.2 A parabolic trough collector cut in half.

2.2.2 Flat-plate solar collector

The most widely known type of solar collector is the flat-plate collector. In essence, a flat plate collector is a part that faces the sun. A flat plate collector is often consist of an insulated metal box with a glass or plastic cover and a dark-colored absorber plate. Flat-plate collector is a crucial device for harnessing solar energy at low temperatures, indicating its significance in various applications such as solar water heating and space air heating. Solar radiation is absorbed by the flat plate solar collector cover plate. Some of the solar radiation is turned immediately into heat energy, while the remainder travels through the cover plate and is converted further into heat at the heat absorption plate (Dengjia Wang, 2022). By adjusting the mass flow rate, the solar thermal system's network architecture may be changed and working fluid inlet temperature was conducted by Amanda L et al. (2019) aims to achieve the lowest feasible collector surface area while still fulfilling the process's necessary heat conditions. The network structure, this is composed of the quantity of parallel lines and the quantity of series collectors on each line, is critical in system design and must be proportional to the desired delivery temperature, the system's heat burden must deliver need to fulfil the thermal demands of the process. Although, the flat plate solar collectors are the foundation of the design technique, it can also be applied to other low-temperature solar technologies. The flexible operating and design issues of solar thermal utility systems for low-temperature processes, especially utilising flat plate solar collectors. Khanmohammadi et al., (2020) found the flat plate air solar collector's and the integrated ocean thermal energy conversion system's sustainability index values, which ranged from 1.949 to 2.220. The thermal conductivity characteristics within the air gap of a horizontal flat plate thermal solar collector that incorporates partitions attached to its glazing and the absorber and glass are kept at constant but differing temperatures, while the vertical walls (insulation) are treated as adiabatic. Next, the impact of the number and length of fins on the air pattern and heat transfer within the collector has been investigated. It can be observed that the heat transfer rate through the air gap is significantly affected and can be controlled by manipulating the number and length of the fins attached to the glazing. So, the use of partitions within the collector has been shown to minimise heat losses through convection by 90% (Adel laaraba, 2019). Air-based collectors are a specific category of solar collectors that employ air as the medium for heat transfer, as opposed to using a liquid. In these collectors, the solar energy absorbed is converted into heat, which is then stored in containers, such as those filled with materials like gravel. The energy harnessed from air-based solar collectors finds application in various areas, including ventilation air heating, space heating, and crop drying (air-based collector, 2016). The table 2.1 show enumerates different types of air-based collectors and their respective suitability for these three primary applications and Figure 2.3 air flat plate collector.

Table 2.1 Enumerates different type of air based collector

Type of collector	Ventilation air heating	Space heating	Crop heating
Unglazed perforated plate	Very good	Poor	Very good
Glazed flat-plate	Good	Poor	Good
Back-pass	Fair	No	Fair-good
Trombewall	No	Good	No

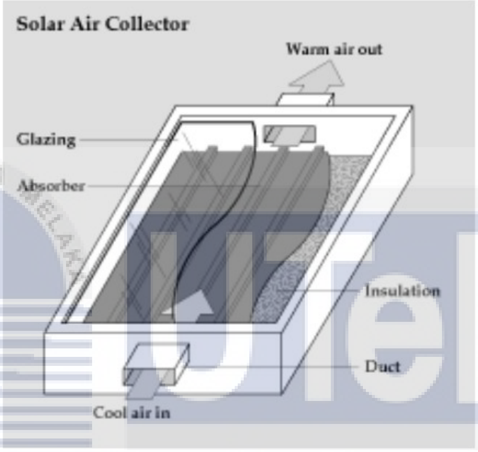

Figure 2.3: Air flat-plate collector.

2.2.3 Evacuated tube collector

Evacuated tube collectors differ from other types of collectors in their design and operation. This collector is made up of several glass tubes made of annealed glass that is placed inside each inflatable. The effectiveness of solar collectors using evacuated tubes, including its potential for higher energy savings, comparisons with flat plate collectors in various situations, and the influence of design parameters such as reflectors and flow rates on its efficiency. Evacuated tube solar collectors are better than flat plate collectors in terms of solar energy production, especially during colder seasons, resulting in more consistent thermal energy generation. The evacuated tube collectors show better productivity and higher heat gains, particularly during colder periods (Piotr Olczak, 2020). An evacuated tube collector is made up of modular tubes that are linked to a header pipe. To minimise heat losses to the environment, the water piping is enclosed by concentric glass tubes with a vacuum in between and a selective coating to boost solar radiation absorption and restrict emissivity in the infrared spectrum. This collector was operating to transport heat efficiently, use liquid-vapor phase transition materials (Simona Di Fraia, 2020). However, direct flow or a heat pipe is used in evacuated tube collectors. The fluid in the primary loop flows directly through the absorber pipe in direct flow. The advantage of this configuration is that a heat exchanger is not present, hence inefficiencies are avoided. Direct flow evacuated tube collectors can be used with heat transfer oils or for direct steam production in addition to water heating (Brian Norton, 2022). An evacuated-tube collector is made up of a series of modular tubes that are vacuum-sealed to reduce convective heat losses. The absorber plate is a metal strip that runs through the centre of each tube, and a heat pipe transports the gathered energy to the water, which circulates via a header at the top of the pipe array (Zhangyuan Wang, 2018). Figure 2.4 shown a water collector with evacuated tubes in hot system.

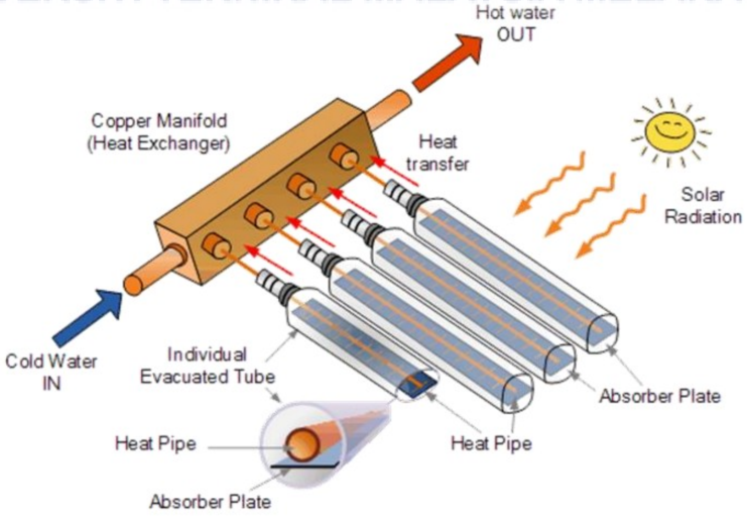

Figure 2.4: A water collector with evacuated tubes

In an evacuated tube collector (ETC) arrangement, the solar air heater equipped with helical coiled inserts (ETC-HI) is the main subject of this article's performance analysis. The research includes testing the ETC-HI system in conjunction with a standard ETC solar air heater at various mass flow rates ranging from 0.003 to 0.015 kg/s. Analysis of the helical evacuated tube's effects on variables such temperature at pressure losses,the outflow, heat gain, and thermal performance, during both normal and reversed system operation was the goal. The results showed that the ETC-HI system produced an average air temperature of 95.5°C at a mass flow rate of 0.003 kg/s, with a maximum air temperature at the exit of 112.6°C. Additionally, the ETC-HI solar air heater outperformed the basic ETC solar air heater, which only achieved a maximum thermal efficiency of 64.5%, at a mass flow rate of 0.015 kg/s. Despite a 2.45 times greater pressure drop, the ETC-HI system's effective efficiency outperformed the standard ETC system without having any adverse effects on the economy (Inderjeet Singh, 2021). Figure 2.5 shown an evacuated tube solar air heater with helical insert.

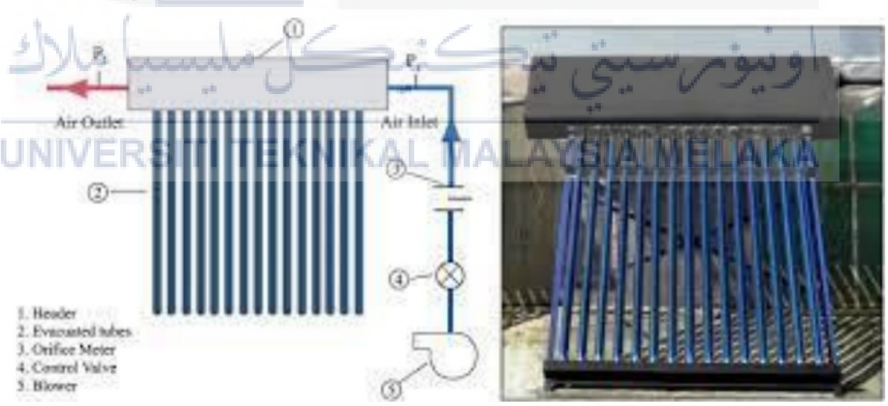

Figure 2.5 Solar air heater in an evacuated tube with a helical insert.

2.3 Type of pass collector

Solar air heaters were divided into two groups. One type is a single-pass solar air heater in which air travels over the absorber plate in a single pass only to absorb heat from it. The other type is double-pass solar air collector. Numerous researchers have experimented on single and double-pass solar air collectors to enhance their thermal performance, which is often poor due to inefficient heat transmission between the absorber plate and the air. According to the literature, increasing turbulence improves thermal efficiency. Below sub-section describes detailed studies related to the solar pass collector.

2.3.1 Single pass collector

Single-pass collector, also known as a flat plate collector, increases air temperature, heat and dryness, crop dryness in the area, space heating, and industries where this hot fluid is necessary for many chemical reactions, as well as for applications where the fluid temperature must be less than 100°C, using a thermal transfer device that absorbs solar radiation and converts it into heat. (Kumar, Neeraj, 2019). A series of experimental tests were performed systematically, and a study conducted by Alvarez et al. (2004) showed a significant improvement in thermal efficiency for single-pass solar air heaters using internal fins and absorbent plates. The experiment conducted by Alic and Erdem, (2021) examined the thermal and environmental impacts of four different designs of solar air collectors (SAC). The study emphasised the significance of the absorber plate surface area and the fluid inlet cross-section area, which affect thermal effectiveness of the SACs. The thermal efficiency was analysed, revealing that although the Z-type SAC achieved an average efficiency of 78%, there is room for improvement in terms of temperature, velocity, and pressure distribution patterns. A well-designed collector that can generate heat while remaining relatively inexpensive over time. The absorber plate and ducting are critical collector components for heat to be transferred and conducted on the plate. Figure 2.6 shows the cross-sectional view of a single-pass solar collector. Collectors should have a tilting surface to absorb the most solar energy, with the angle of tilt variable depending on latitude and day of the year. Collectors are simple to construct and need minimal maintenance.

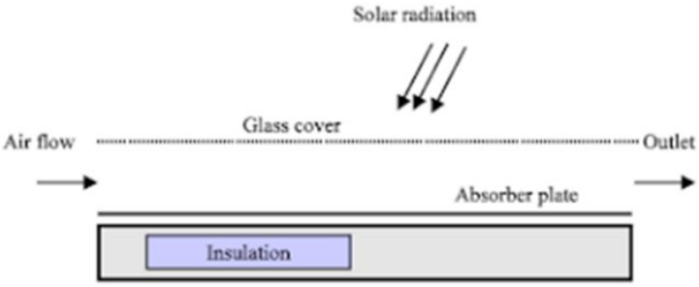

Figure 2.6 Cross-sectional view of single pass solar collector.

2.3.2 Double-pass collector

A double pass collector is one of the most efficient techniques for drying crops since air is heated from both sides of the absorbent plate (Srinivasan et al., 2018). The experimental evaluation of a double-pass solar air collector with integrated triangular fins highlights the fins' positive effect on thermal efficiency. The study shows that including fins in the collector design resulting in increament of heat transfer and thermal performance, providing insights for the construction of more efficient solar collectors (Machi, 2021). In addition, there is an investigation of a double-pass solar collector using wooden shields below the absorbing plates. conducted by Dhaundiyal (2022) to investigate the solar collector performance and efficiency by analysing the flow behaviour and energy of air that affected the mass flow rate, momentum thickness, shear stress, and placement of fins. Chávez-Bermúdez, (2022) states that utilising a double-pass arrangement holds promise for enhancing the thermal efficiency of solar air heaters and attaining elevated efficiencies. The design incorporates a U-shaped double-pass configuration, allowing the air to initially enter the duct to capture solar energy for heat gain. Subsequently, it passes through the hollow section, facilitating further heat transfer and optimisation of the system's overall performance. Moreover, the collector produces much higher output temperatures because of utilizing a double-pass design and the addition of fins, suggesting increased thermal performance (Nguyen,2020). The creation of solar energy applications for drying agricultural products, offering sustainable and effective substitute for traditional drying techniques. The high flow rate is a crucial feature of the double pass collector. Figure 2.7 depicts a cross-sectional view of a double-pass solar collector.

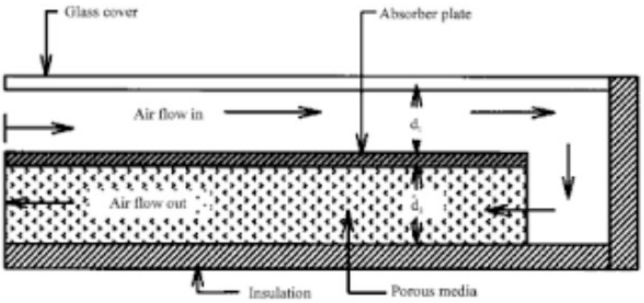

Figure 2.7 A cross-sectional view of a double-pass solar collector

2.4 Fin arrangement in solar collector

Fin arrangement in double pass solar collector is use to increase the heat transfer between the absorber plate and the air passing through the collector. When the surface area of the fins arrangement is large, it will facilitate heat transfer and can enable more effective heat transfer from the absorber plate to the air entering the double pass solar collector. The arrangement of the collector fins affects the distribution of airflow across the absorber surface. A well-designed fin arrangement can improve consistent airflow, reducing the possibility of obstruction or skipping heat-transfer regions. However, fins arrangement can affect pressure drop in the double pass solar collector and it will manage the airflow resistance and pressure losses through the collector. Fin solar collector works as an absorber.

Solar radiation that passes through the flat plate to the glass and is routed to the copper risers is used to heat the absorber fins positioned on the copper risers. A spiral prototype with copper risers was constructed, and absorber fins were then attached to it. The absorber fin was produced by incremental sheet forming (Schreiber, 2019). Applying an off-center finned absorber tube improves the parabolic collector's energy efficiency by raising the Reynolds number and lowering the solid volume fractions (Alnaqi, 2021). Additionally, Hao Peng (2021) mentions that the arrangement of fins is beneficial for improving heat transfer by intensifying fluid mixing within the central flow and extending the solid surface to facilitate heat conduction. Furthermore, the insertion of fins at circumferential intervals reduces solid volume, resulting in a decrease in pressure drop. The most effective option for reducing the peak temperature of the outer wall and achieving temperature uniformity is the semi-annular metal tube with triangular fins. This configuration not only minimizes temperature gradients and thermal stress but also enhances the operational safety of the parabolic through collector. Figure 2.8 shows the fin shape of the semi-annular and fin metal hybrid structure.

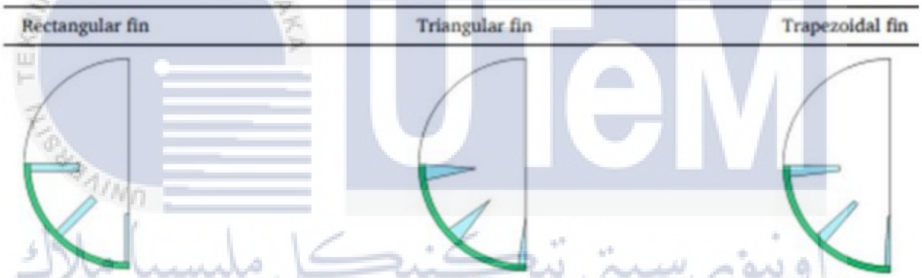

Figure 2.8 Fin shape of the semi-annular and fin metal hybrid structure

Adding fins to a flat plate solar collector was done by applying a heat flux in a steady state and active techniques for fluid circulation. With and without fins, there are two varieties of flat plate solar collectors. According to Alkhafaji (2022), daily thermal performance on average rose by 4% when compared to the situation without fins. Then, the fins were added to the rising pipe to create a flat plate solar collector. It has been established that using fins increases the exit temperature and thermal efficiency by 2% and 25%,. Adding fins also boosts storage capacity, especially for phase-change materials with higher melting temperatures (Z. Badiei, 2020). Other than that, the purpose of the fin is to increase the surface area exposed to the sun's heat, hence increasing radiation heat transmission. The reason for selecting this form of collector is that the area of heat absorption is larger, resulting in a larger surface area of heat transmission from the absorber to the working fluid. Figure 2.9 shows the longitudinal fins flat plate in the solar collector.

Figure 2.9 longitudinal fins flat plate in the solar collector

An experiment was conducted by Ali Daliran, (2018) on how solar air heaters' attached cylinder fins affect the absorber plate. The findings indicate that a well-designed fin arrangement leads to increased temperature of the exhaust air and increased thermal performance compared to a basic, predictable device. Furthermore, the study reveals that solar radiation and air flow rate are the primary factors influencing the thermal performance of solar heaters. Through a 2D numerical simulation, the impact of manufactured texture on heat transmission and friction factor was examined. Results indicate that increasing the absorber plate's roughness increases the friction coefficient, and this in turn raises the heat transfer coefficient. Figure 2.10 shows the staggered fin in a flat plate solar collector.

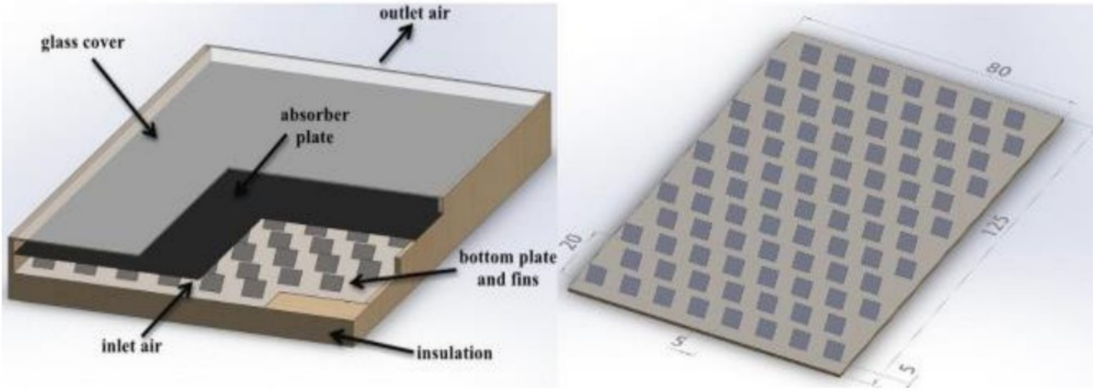

Figure 2.10 The staggered fin in a flat plate solar collector.

The efficiency of an air heating channel is examined in the present work in relation to multi-staggered rib characteristics, especially the W-rib roughness. The novelty of this investigation lies in the unique combination of rib roughness, as such a configuration has not been explored previously. The dimensionless factors investigated include the relative staggered pitch (p/P) ranging from 0.45 to 0.75 and the relative staggered rib length (w/e) ranging from 1.5 to 6.0. These factors were varied to analyze the impact of staggered ribs on the solar air heater channel within a Reynolds number range of 4000 to 14000, which is considered suitable for the application (Sushant Thakur,2020). Figure 2.11 shows The of 'W'-shaped roughness on solar air heater performance

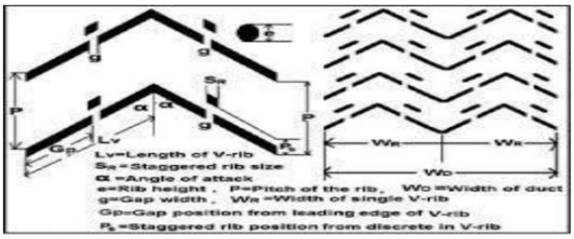

Figure 2.11 The of 'W'-shaped roughness on solar air heater performance

The influence of the spacing between the ribs (e) on thermal performance of the present solar air heater is quantitatively investigated in this section three different separations between the ribs e^1/4, 5, and 10 mm are chosen. There are four Reynolds values used in the simulations, which range from 6000 to 12000. All three rib characteristics aspect ratio (AR), pitch (P), and height (a) are kept a constant at 1, 40 mm, and 2 mm, respectively. The schematics of the models under consideration, with varying distances between the ribs (Hamid Kazemi Moghadam, 2021). Figure 2.12 shows schematics of the models under consideration for various rib spacings (e).

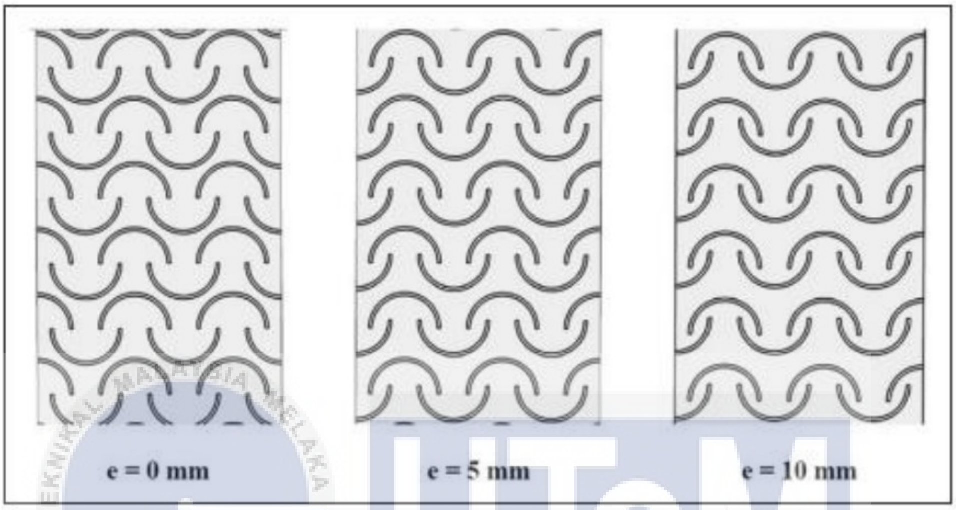

Figure 2.12 Schematics of the models under consideration for various rib spacings (e)

This study conducted by Ahmad Fudholi et al., (2010) is to assess the thermal efficiency of a solar air collector using forced convection and staggered fins. Variations in the amount of solar radiation and mass flow rate were used to evaluate the collector's efficiency. Additionally, there were found significant links between operational circumstances and design. The results show that at a mass flow rate of 0.083 kg/s and solar radiation of 788 W/m², the double-pass solar collector with staggered fins achieves an efficiency more than 75%. Moreover, the rate of mass flow and sun radiation have a major impact on the solar collector's efficiency., with the efficiency increasing in direct proportion to both variables. Figure 2.13 shows top view of the staggered fin in double-pass solar collector.

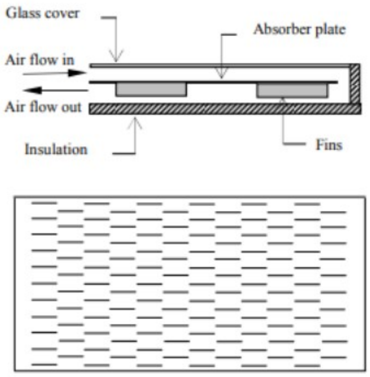

Figure 2.13 Top view of the staggered fin

2.5 Solar air dryer application

The solar air collector system uses the renewable energy of the sun to heat the air. This device is produced to minimise the dependence on traditional heating techniques that use fossil fuels or electricity that have an impact on the environment. This will save energy, reduce carbon emissions, and be environmentally friendly for space heating and ventilation.

Even though solar air heaters play a vital role in drying agricultural crops, their availability in convection-free mode is quite restricted. The thermal performance of such a convection-based solar air heater may be enhanced by causing the air to experience a significant pressure drop over the heated air thermal collector. Gaps or fin on the absorber surfaces may be used to do this, which lowers the hydraulic efficiency of air while boosting the rate of mass flow (Prakash, 2023). Flat plate heating solar collectors are often used for drying in business, agriculture, and household laundry in addition to space heating in houses. The paddy drying application made use of the longitudinally rectangular fin in the flat plate of a single pass solar air heater. As the total amount of fins grows, the temperature of the outflow air rises and subsequently falls, but the pressure drop climbs with the number of fins. According to the analysis, the optimum finned plates air heating solar collector for paddy drying applications has 80 fins, a height to duct length ratio that is 0.6, and a fin layer thickness of 2 mm.

(Bhattacharyya, 2016). The temperature within the drying chamber is the most critical characteristic that directly influences the drying rate. Nonetheless, the changing weather conditions and the intermittent nature of solar energy have a significant impact on the temperature threshold of drying air. As a result, the quality of the dried items suffers significantly. Solar energy is used effectively to improve heating and drying performance. In term of the drying performance, an experiment was conducted to dried apple slices in food drying systems using fixed and moving solar air collectors at the same time (Mehmet Das, 2020). Figure 2.14 shows the application of solar drying system to dry apple slices.

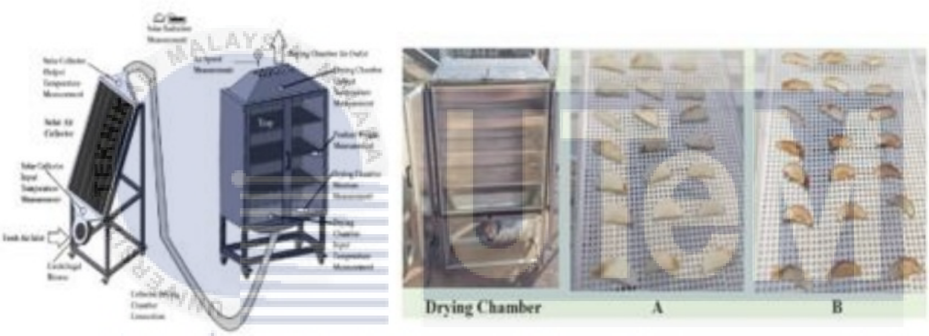

Figure 2.14 The application of solar drying system to dry apple slices.

Solar dryers, available in various design variants, are energy systems that effectively harness the power of the sun to enhance their thermal efficiency. The utilisation of solar energy in drying systems can lead to significant reductions in the need for fossil fuels, resulting in substantial savings (El Hage et al., 2018). By sending hot air over a solid substance to remove the produced vapour, drying is a mass and heat transfer event that removes moisture. Uptake of moisture continues until the product's and the environment's vapour pressures are equal (Ekechukwu and Norton, 1999). This study aims to provide an extensive overview of the various types of solar dryers employed in food applications, emphasizing their distinct design characteristics that influence both the performance a dryer's efficiency and the product's quality

(Y. Mohana et al., 2020). According from Eshetu Getahun,(2021) fruits and vegetables that are improperly handled suffer severe postharvest losses. Solar dryers have been suggested as one of the postharvest preservation techniques that is acceptable and sustainable for fruit and vegetable goods. The most recent developments, in this research, possibilities and challenges related to sun drying of fruit and vegetable products are examined. In addition, the paper examines the popular mathematical models for solar dryer evaluation, design, and optimisation. The review discusses the effectiveness of sun drying methods in terms of duration of drying, dryness rate, and quality of the product factors. An efficient solar dryer requires a short drying time, consistent air velocity, temperature, and food wetness distribution across the drying chamber. Prototype 1 was a solar collector placed on top of a drying chamber with a 20° slant. The solar collector used three 12 V fans to pump air through perforated and painted black aluminium cans, bringing hot air into the dehydration chamber below. The collector top has a 4 mm window glass to prevent convective losses. The drying chamber had numerous plastic sliding trays with varying mesh sizes that could be adjusted depending on the type of product we wished to dry. The stand's base was outfitted with swivel wheels for mobility (Lisete Fernandes et al., 2022). Figure 2.15 shows a solar panel for drying fruits

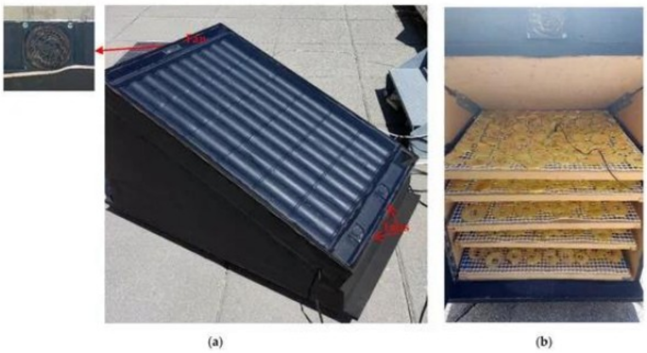

Figure 2.15: Solar panel for drying fruits

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter covers the progress flow chart and project planning used in this project. Fins and double-pass are some of the features included in the model. The different of fin arrangement has been proposed which is straight fins, staggered fins, and pin fins. These collectors are made up of an absorber plate, a transparent cover, and a fluid that transfers heat via a duct. One of the crucial factors influencing the performance of double pass solar collectors is the design and arrangement of fins within the duct. The proper understanding of how different fin arrangements affect the air flow behavior is essential for optimising the collector's efficiency. This model has been enhanced to improve the solar collector's performance even more. For the analysis to be performed, several parameters have been set. After that, CFD simulations are conducted to investigate the airflow behavior within the collector duct. The study's findings will be compared to the method of calculation that has already been used.

3.2 Process flow chart

Figure 3.1 illustrates the workflow for completing this project. The subsequent step involved conducting a literature study to gain a deeper understanding of flat plate collectors for drying systems. After that, computational meshing of the model was necessary before running CFD simulations. The project will then proceed to estimate the parameters required for conducting CFD analysis using ASNYS Software. Subsequently, the analysis of the model will be documented, and additional decisions will need to be made.

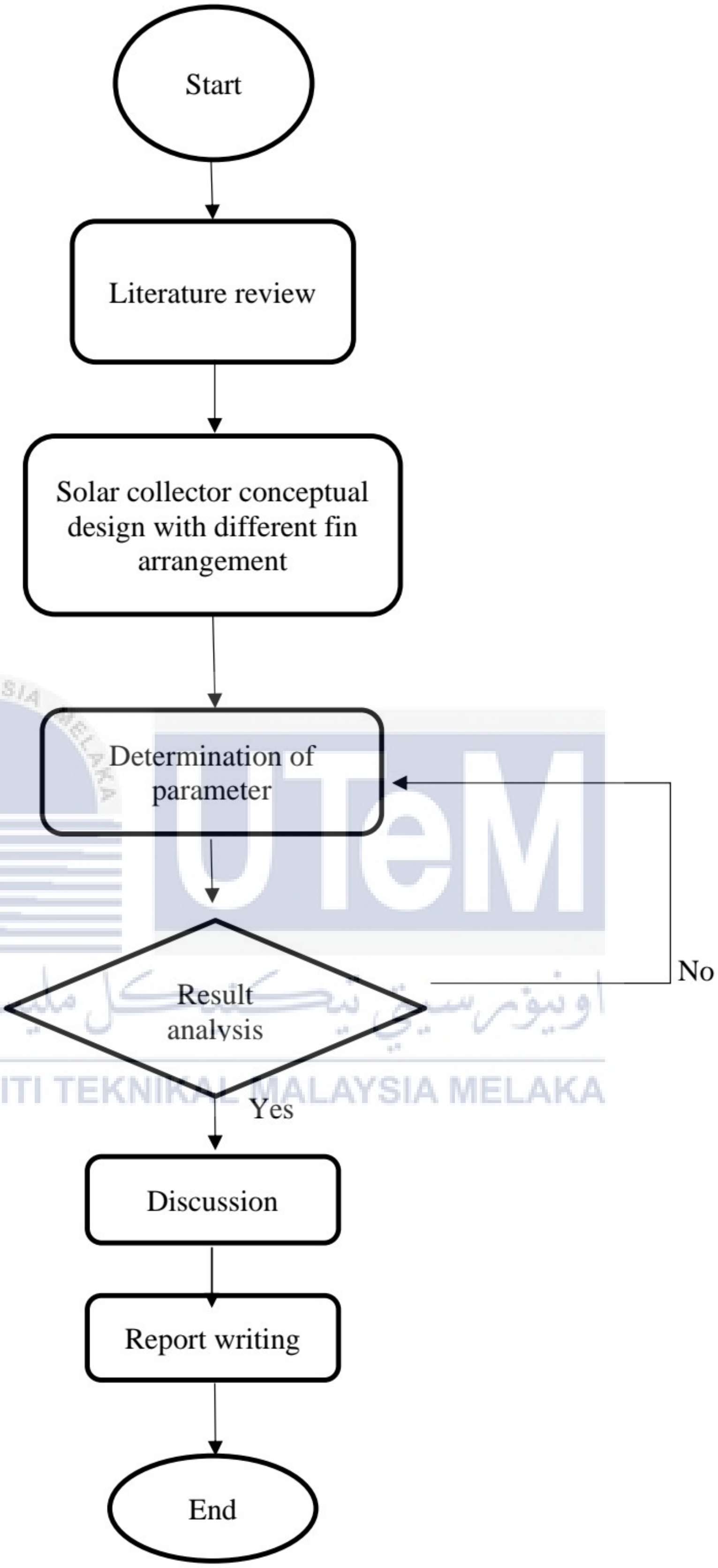

Figure 3.1: Flowchart of the project process

3.3 Design geometry

The new design's goal was to divide the air conduit into two channels (upper and lower), essentially creating double-pass solar collector by putting a black painted plate into it. The purpose of this research was to introduce a double-pass collector that could generate higher air temperatures in a shorter duration. The focus of this study was to develop a drying system utilizing double-pass solar collector. Specifically, the emphasis was on incorporating fins in the second air passage of the double pass counter-flow solar collector to enhance thermal performance. The results indicated that the thermal efficiency of a double pass solar air collector with porous absorbing material was 20-25% and 30-35% higher than that of a double pass solar air collector without porous absorbing material and a single pass collector, respectively (Fudholi et al., 2013). The geometry of the model was designed using SolidWorks CAD software.

The total measurement for design solar air collectors is 1200 x 1800 x 68 mm^3 with a 4 mm thick glass plate. A sheet of stainless steel with thickness 10 mm and 1695x1190 mm2 area attached with different fins attached to its lower surfaces was used as the absorber plate. The height of the fin is 20 mm. To provide insulation, foam material with a 5 mm thickness was utilized to insulate the solar collector from the back and sides. Within the collector, the absorber plate separates the space between the lower glass cover and the backplate into two channels, each with a depth of 30 mm. The inlet airflow is positioned in the first passage of the double pass collector and has an area of 1190 x 30 mm^2. In the second passage of the double pass collector, there are three airflow outlets with a radius of 80 mm. The design can be seen in Figure 3.3,and Figure 3.2 and Table 3.1 showed the dimension and design solar collector and part dimension of solar collector.

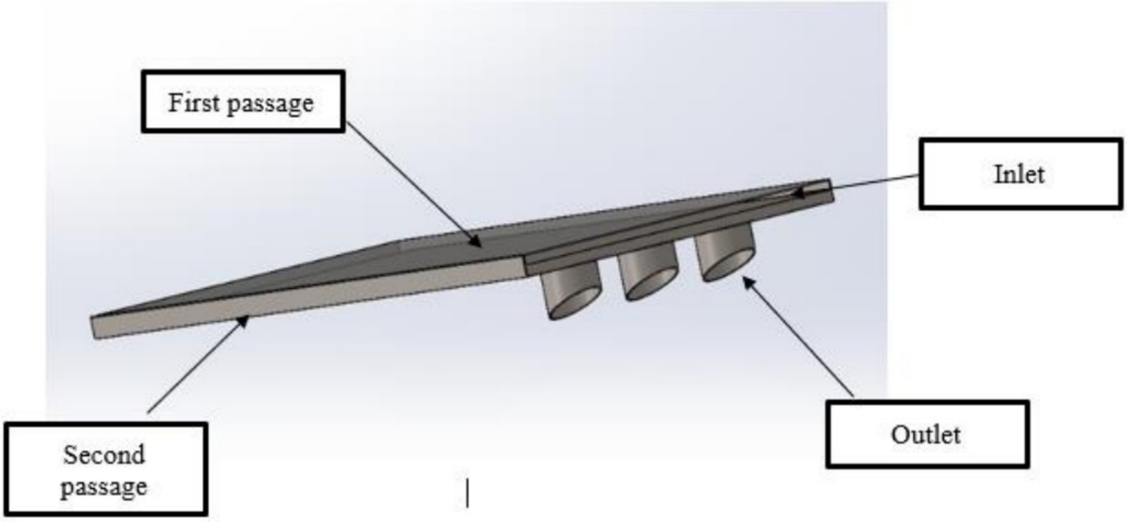

Figure 3.2: Design of solar collector

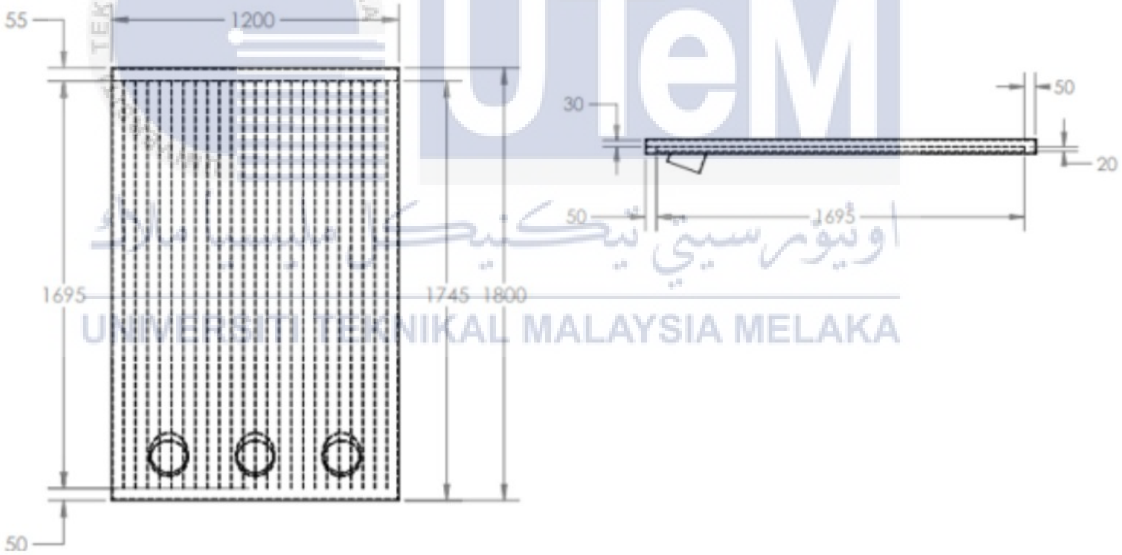

Figure 3.3: Dimension of solar collector

Table 3.1 Part dimension of solar collector

Part	Dimension (mm)	Quantity
Absorber plate	1695 x 1190	1
Glass	1800 x 1200	1
Inlet	1190 x 30	1
Outlet	R80	3

3.3.1 Straight fins design

A straight fin is a type of extended surface commonly used in heat transfer applications. It is a thin, elongated structure that protrudes from a base surface. The straight fin extends perpendicular to the base surface. 13 straight fin has been designed and the distance between two adjacent fins and fins height are 47.6 mm and 20 mm, respectively. The design and placement of straight fins depend on factors such as available space, thermal conductivity of the fins, and the characteristics of the fluid or air. Figure 3.4 and 3.5 show the solar collector with straight fins and top view of solar collector.

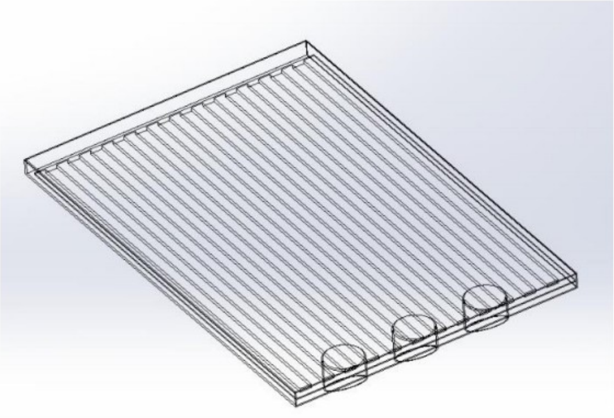

Figure 3.4: Design solar collector with straight fins

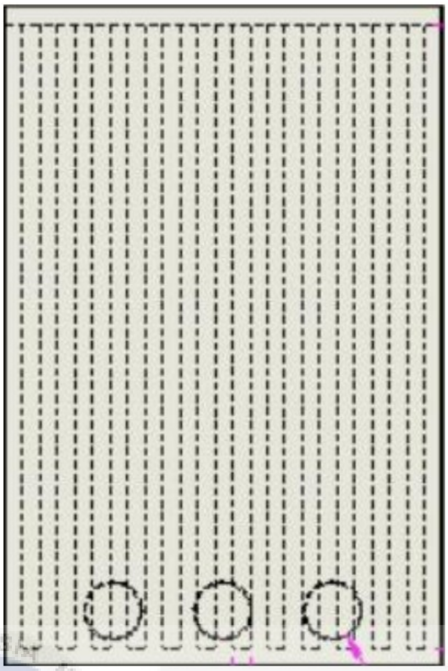

Figure 3.5: Top view of solar collector with straight fins

3.3.2 Solar collector with staggered fins

Staggered fins, also known as offset fins, are a type of extended surface commonly used in heat transfer applications. The staggered arrangement of fins aids in disrupting the flow of fluid or air travelling over the surface, hence increasing heat transfer. This disruption improves mixing and decreases the development of boundary layers, resulting in higher convective heat transfer coefficients. Dimension of the staggered fin are 440 mm x 60 mm x 20 mm and 17 staggered fin has been designed. The staggered fins are not lined up in a straight line. They are instead organised in an offset configuration, with each row of fins moved or staggered relative to the next row. So, the distance between the left and right staggered fins is 80mm while the distance between the top and bottom fins is 100mm. Figure 3.6 and 3.7 shows the actual solar air collector with staggered fin and the top view of solar collector drawing.

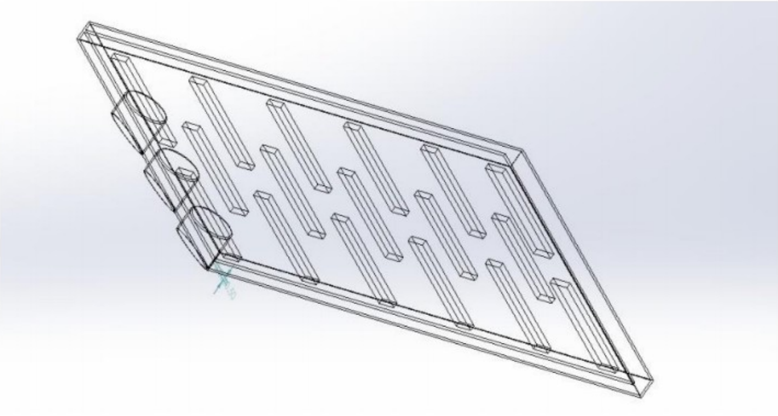

Figure 3.6: Design solar collector with staggered fins.

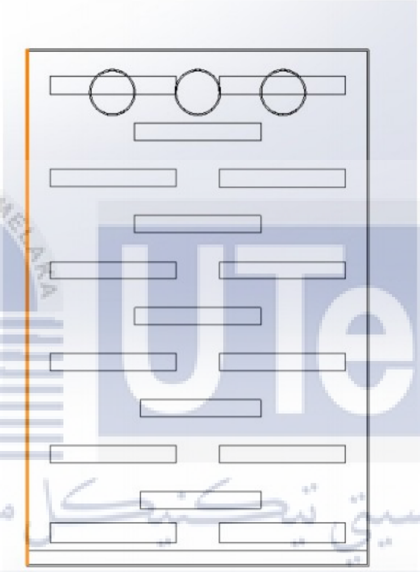

Figure 3.7: Top view of solar collector with staggered fins

3.3.3 Solar collector with pin fins

The pin fin solar collector is a form of solar collector that uses pin-shaped fins to improve heat transmission from the absorbed sun energy to the surrounding air. It is made up of a base plate with several cylindrical pins emerging from it. The dimensions of the pin fins, such as their height is 20 mm and radius are 60mm. In this model there are 54 pin fins that have been produced. Figure 3.8 and 3.9 shows the solar collector with pin fin and the view of the solar collector.

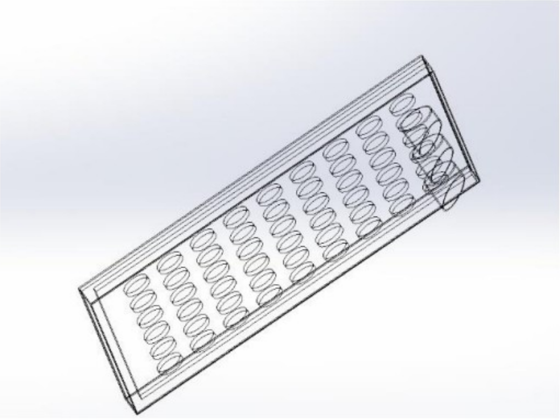

Figure 3.8: Design solar collector with pin fins

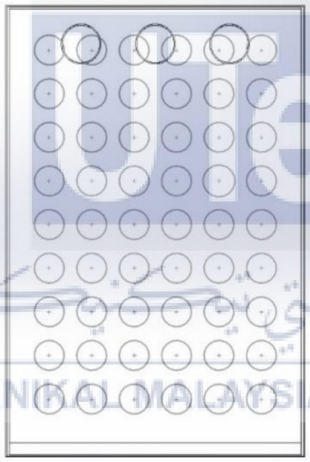

Figure 3.9: Top view of the solar collector with pin fins

3.4 Selection of materials

Materials, which are physical things, serve as the foundation for CFD analysis. The two types of materials that can be employed in research are fluids and solids. In this study, the solar collector for the drier process was created from a range of materials. All the materials used in this study are specified since they were required for computational fluid dynamics (CFD) analysis. This data will be analysed using Ansys Software. Table 3.2 shows a list of materials and their intended uses.

Table 3.2: A list of materials and their indeed uses

Material	Part
Stainless steel	Entire solar collector
Glass	Transparent cover

3.4.1 Stainless steel

Stainless steel is a broad phrase that refers to a variety of steel kinds. Stainless steel, like all other varieties of steel, is created largely from iron and carbon in a two-step process. Steel corrodes for a variety of causes. To begin with, iron, the metal used to manufacture steel, is mixed with other components. When iron ore is artificially refined to manufacture steel, it becomes unstable and rapidly recombines with oxygen. Second, when chromium is added to steel, chromium oxide is formed, which works as a protective surface, preventing corrosion caused by air and moisture, as is the case with conventional steel. Chromium is added in levels ranging from 10.5 to 30% depending on the application or environment in which the steel is utilised.

Majid et al., (2015) state that this stainless steel solar collector is intended for use in the food industry. Because of its high chromium content, stainless steel is corrosion resistant and does not respond to high temperatures within the solar collector. This is required to guarantee that the product is manufactured in a clean environment. Furthermore, while stainless steel can absorb a lot of heat, it has a sluggish rate of energy propagation. Aluminium, on the other hand, can absorb a lot of heat but has a slow energy transmission rate due to its high thermal diffusivity. Stainless steel does not rust either. As a result, it is suited for use in severe areas where solar collectors are commonly deployed. Furthermore, owing to sand, moisture, and corrosion, stainless steel is a good choice for fastening for heliostats outside.

Stainless steel, unlike certain other metals, is resistant to wear and the formation of fissures over time. Bacteria may colonise cracks, chips, and dents, creating a health danger. Stainless steel is a material that is designed to be long-lasting. The bulk of solar collectors are built to endure a long time. Stainless steel is the best material for this purpose since it will almost always last longer.

3.4.2 Glass

Glass is a great glazing material for solar collectors. Most commercial solar collectors utilise tempered glass with good transmission (low iron). The most often utilised glazing materials are glass and polymers. Glass is the most frequent material used to glaze solar collectors. Glass transmits up to 90% of incoming short-wave radiation, which is a very desirable feature. In contrast, almost no long-wave radiation released by the absorber plate may escape via transmission. As a result, a plastic cover outperforms a glass cover in terms of short- and long-wave transmittance and performance. Plastics, on the other hand, have a short life period owing to UV radiation, which lowers their transmissivity.

The front cover of the solar collector in this project is made of glass. The glass measures 1800 x 1200 mm in size and are 4 mm thick. Glass as a front cover decreases the absorber's convective and radiant heat loss, transmits incident solar energy, absorbs the absorber plate with minimum loss, and shields the absorber plate from the environment. To achieve optimal efficiency, reflectivity and absorption should be as low as possible, while transmission should be as high as possible. When compared to glass thicknesses of 3mm, 5mm, and 6 mm, 4 mm glass enhances solar air collector performance by 7.6%; however, the chance of glass breakage during construction is greater when utilising thinner glass, 4 mm vs 5 mm and 6 mm (Bakari et al., 2014).

3.5 CFD Analysis

Computational fluid dynamics (CFD) analysis. It is a computer program used to research and model fluid flow and heat transfer systems. In order to anticipate computational fluid dynamics (CFD), mathematical equations regulating a variety of fluid flow, heat and mass transfer, chemical processes, and scientific events are numerically solved.

Computational fluid dynamics (CFD) methods were utilised in This research will simulate solar collectors in order to better comprehend their heat transmission capability. To begin, a three-dimensional model of the double pass collectors using various fin arrangements is created in Solid Works. The results were then obtained using the Ansys Fluent software. This study aims to gain a deeper understanding of the computational fluid dynamics airflow and distribution of temperatures within the solar collector.

A solar collector's performance is measured using a number of metrics and values that characterise its properties. The efficiency of a collector is determined by its design, construction, materials, and operating conditions. The fluid selected to represent the solar collectors was air. The working fluid is air, which is a compressible fluid. The initialisation procedure by inlet must be performed to solve numerical equations after all boundary conditions have been set in fluent software. Table 3.3, 3.4, and 3.5 show the properties of stainless steel, glass and airrespectively, which will be used in Ansys simulation.

Table 3.3: Properties of stainless steel

Property	Value
Density	8050 kg/m³
Thermal conductivity	15 W/m.K
Specific heat	520 J/kg.K

Table 3.4: Properties of glass

Property	Value
Density	2500 kg/m³
Thermal conductivity	1.38 W/m.K
Specific heat	910 J/kg.K

Table 3.5: Properties of air

Property	Value
Mass flow rate of air	0.0105 kg/sec
Density	1.165 kg/m³
Thermal conductivity	100 W/m.K
Specific heat	1005 J/kg.K

3.6 Method and simulation

The collector must function properly for this system to work. Air is fed to the solar collector by an intake on the first channel. After the sun energy has passed through the transparent glazing material, the absorber plate absorbs it. This plate warms up and transfers the heat to the air that is confined between the absorber plate and the glazing. By rerouting the air to the bottom surface of the absorbent plate, the double pass collector raises the air temperature. Three outlets at the bottom of the solar collector will allow the warm air to leave. The surrounding walls are considered to receive no solar radiation. . Critical parameters such as outlet air temperature, outlet air velocity, and mass flow rate are evaluated along with absorber plate temperatures. Figure 3.10 shows boundary condition to simulate the solar collectors.

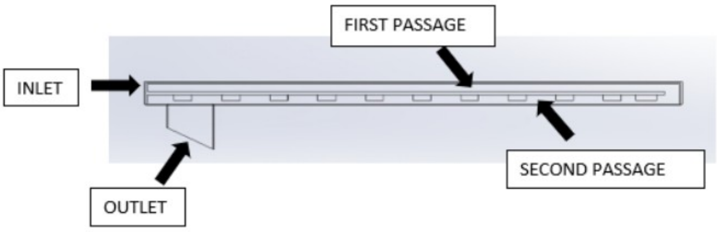

Figure 3.10: Top view of the solar collector with pin fins

3.7 Meshing

The meshing function in Ansys Fluent is a crucial element of the simulation process, since it entails generating a computational grid that covers the specified geometry. The grid, consisting of individual components or cells, divides the domain into smaller parts to simplify the numerical solution of fluid dynamics equations. Ansys Fluent provides a range of meshing techniques, such as structured and unstructured methods, which enable users to customize the mesh according to their individual simulation needs. The focus is on ensuring precise outcomes by prioritizing mesh quality, which includes the provision of tools for assessing and enhancing quality. Boundary conditions are used to specify the behavior of flow variables at the borders of a domain. The meshing function incorporates several factors, such as element size, near-wall refinement, and grid density, which have an impact on the correctness of the solution. On this research, this meshing procedure has been applied to three different kinds of solar collectors, namely straight fin, pin fin, and staggered fin, prior to the execution of a more in-depth simulation. In order to go further with the Ansys Fluent simulation, the mesh that was built for each solar collector is of sufficient quality. Figure 3.11, 3.12 and 3.13 shows that mesh for straight fin solar collector , pin fin solar collector and staggered fin solar collector.

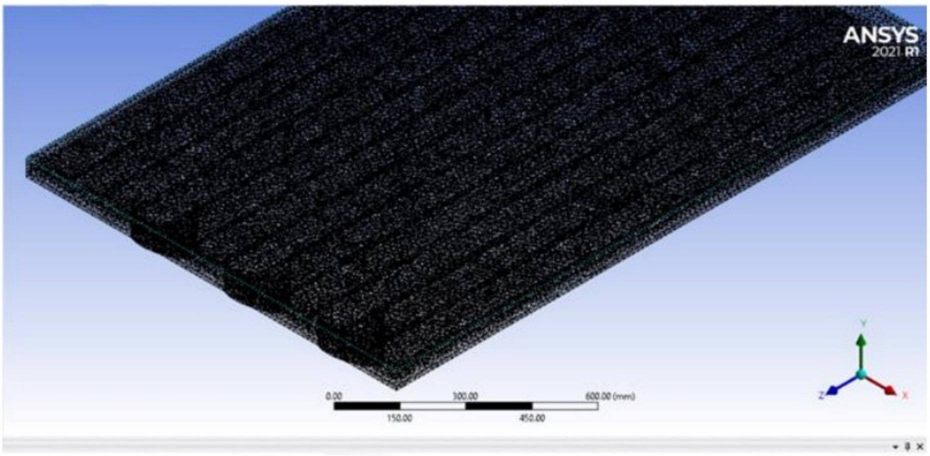

Figure 3.11 Mesh Straight Fin

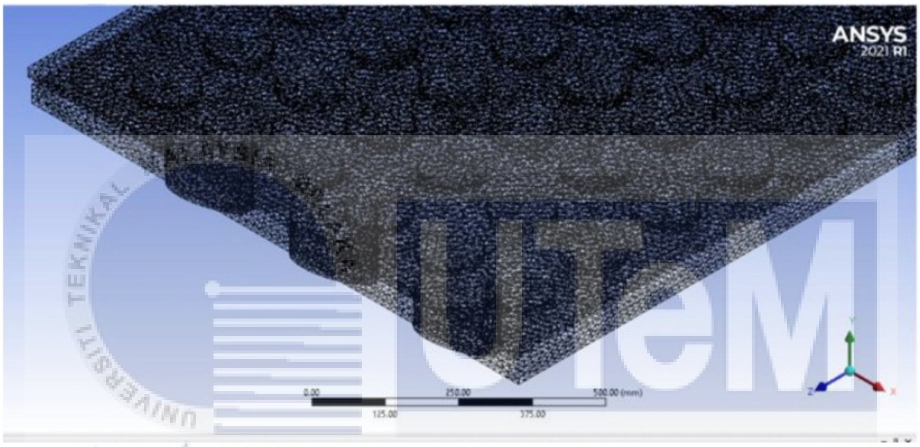

Figure 3.12 Mesh Pin Fin

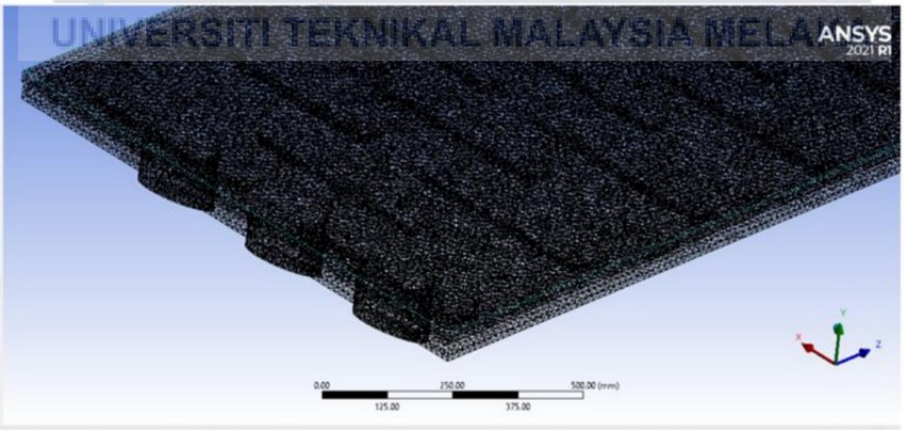

Figure 3.13 Mesh Staggered Fin

3.8 Summary

In brief, employing computational fluid dynamics (CFD), this investigation examines the impact of fin design on airflow within a double-pass solar collector. The double-pass solar collector, a solar thermal device, incorporates fins to facilitate the transfer of heat from the absorber plate to the circulating air. Utilizing CFD models, the researchers analyzed the airflow patterns within the collector, considering various fin arrangements, including straight fins, staggered fins, and pin fins.

CHAPTER 4

RESULT AND DISSCUSSION

4.1 Introduction

Ansys Fluent has the ability to generate various simulation outcomes, such as velocity profiles, pressure distributions, temperature fields, turbulence characteristics, and other pertinent data, based on the given physics and parameters in the simulation setup. The findings are essential for obtaining a deeper understanding of the behaviour of the simulated system and for fulfilling the goals of this research. So, this project utilizes the Ansys Fluent software to analyse three distinct types of fin arrangement in solar collectors which is straight fin, staggered fin, and pin fin. Solidwork software was used to develop the solar collector design. All the information required were collected before doing the simulation, such as the geometry, material characteristics, and relevant boundary conditions. Furthermore, the air flow in solar collector with different fin arrangements were observed and compare in this study.

4.2 Air flow of solar collector

The simulation of airflow in a double-pass solar collector with several fin designs, such as straight fin, pin fin, and staggered fin, were conducted. By integrating the geometry, the meshing of the collector, and the specification of boundary conditions, the execution of the simulation displays the patterns of airflow, the distribution of temperatures, and the pressure for each form of fin.

4.2.1 Air flow of straight fin solar

A smooth modeling of a double-pass solar collector with straight fins gives detailed airflow streamline resulting in straight air movement all the way to the exit tubes.. These streamlines show the path of the wind around the straight fins, which helps to understand the heat motion. The smart choices about the shape, fin spacing, and general collector design by looking at the streamlines. This helps improve energy conversion and sustainability in double-pass solar collector uses. Air flowing inside the solar straight fin travels in the same direction of inlet and outlet due to the fin's straight line position. Figure 4.1 and Figure 4.2 show that streamline pattern of air flow for straight fin solar collector..

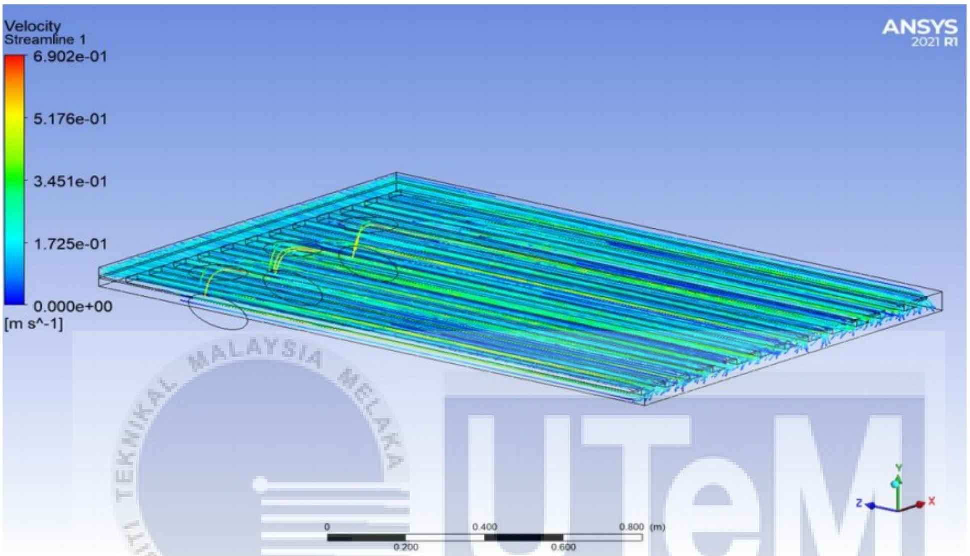

Figure 4.1 Air flow straight fin isometric view

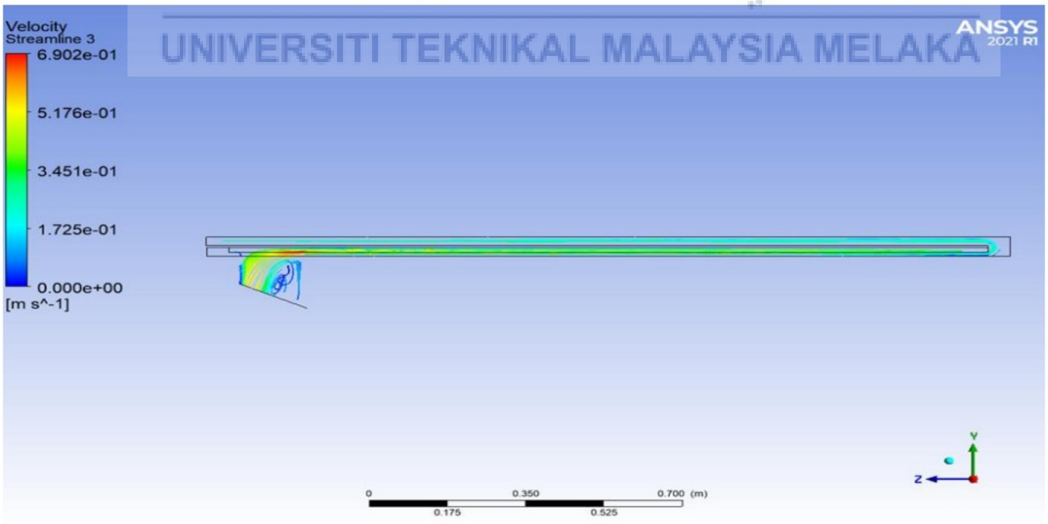

Figure 4.2 Air flow straight fin side view

4.2.2 Air flow of pin fin solar

Airflow streamlines in a double-pass solar collector with pin fins give critical insights into the convective heat transfer process. Air travels over the complicated design of pin fins, impacting heat dissipation and thermal performance, shown by the streamlines. Pin fins, with their larger surface area, change the streamlines in comparison to straight fins, reducing heat transfer efficiency. Figure 4.3 and 4.4 show that air flow in streamline for Pin fin solar collector.

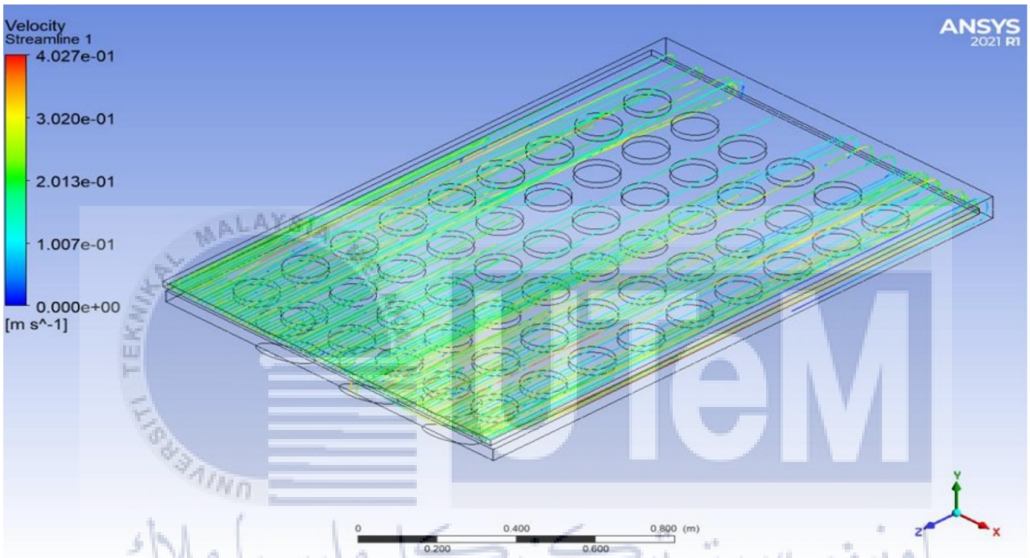

Figure 4.3 Air flow Pin fin isometric view

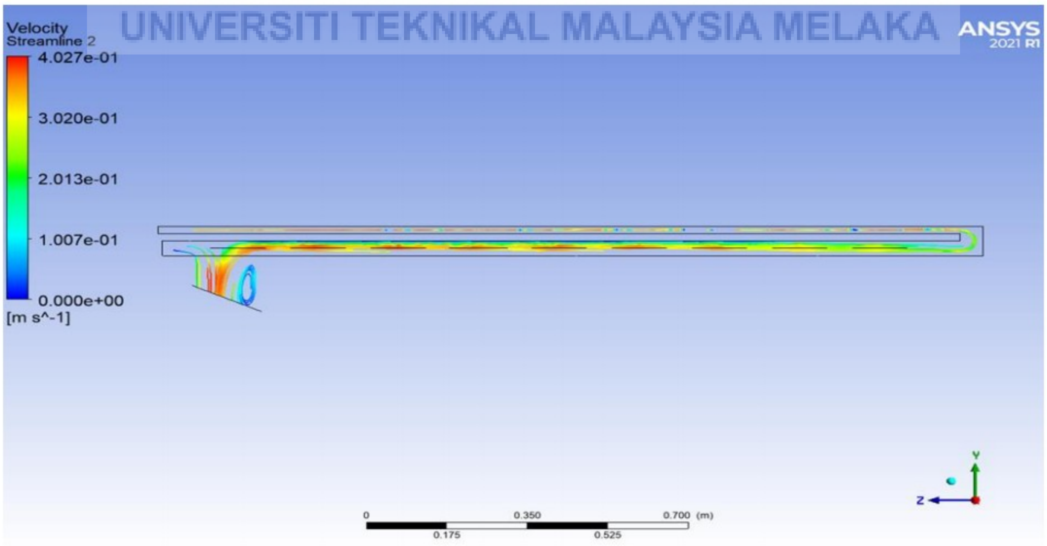

Figure 4.4 Air flow Pin fin side view

4.2.3 Air flow of staggered fin solar

A solar collector with fins arranged in a staggered pattern has a complex flow patterns that occur around the fins, which have an immediate effect on the dissipation of heat.The convective heat transfer properties are affected by staggered fins, which have an offset layout that modifies the streamlines, in contrast to straight or pin fins. Figure 4.5 and Figure 4.6 show the complex streamline of staggered fin solar collector..

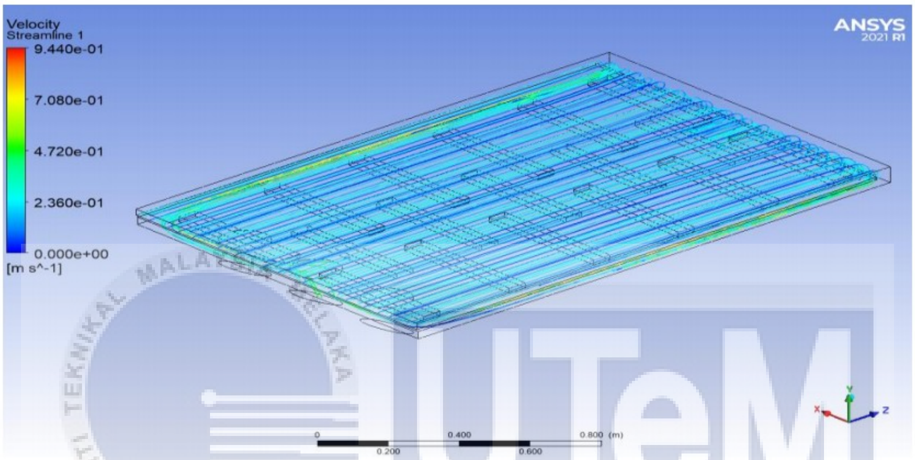

Figure 4.5 Air flow staggered fin isometric view

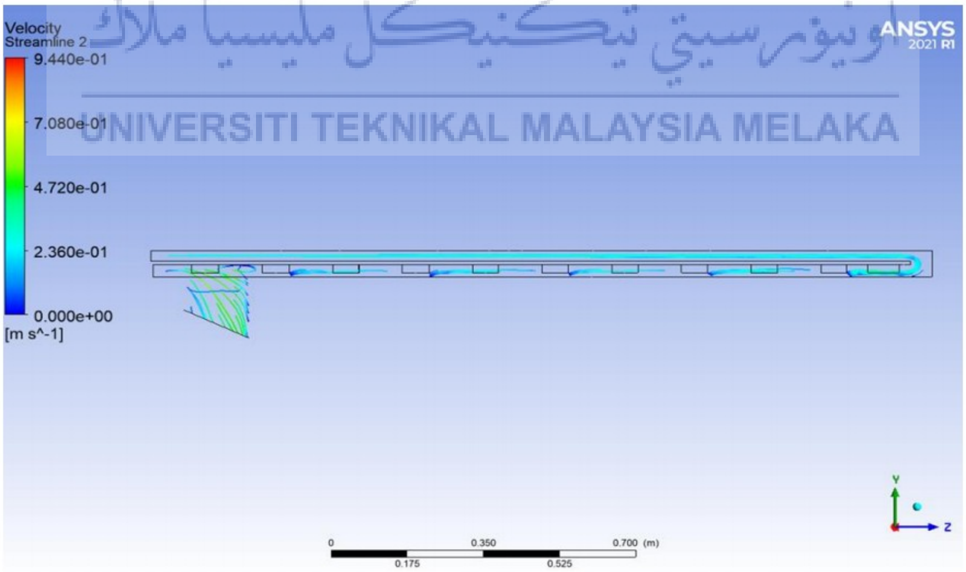

Figure 4.6 Air flow staggered fin side view

4.3 Velocity of solar collector

The word "velocity" refers to how fast and in which direction the fluid moves inside a solar collector. Enhancing heat transfer and energy conversion in solar systems can be accomplished by optimizing the design of the collector based on the airflow patterns identified through the analysis of velocity profiles

4.3.1 Velocity of straight fin solar collector

A double-pass solar collector with straight fins, velocity profiles depict the speed and direction of airflow around the fins. The simulation reveals how straight fins influence air velocity, affecting heat transfer within the collector. The higher velocity that happen in this solar is 6.833e-01m/s. Figure 4.7 show that velocity for Straight fin solar collector.

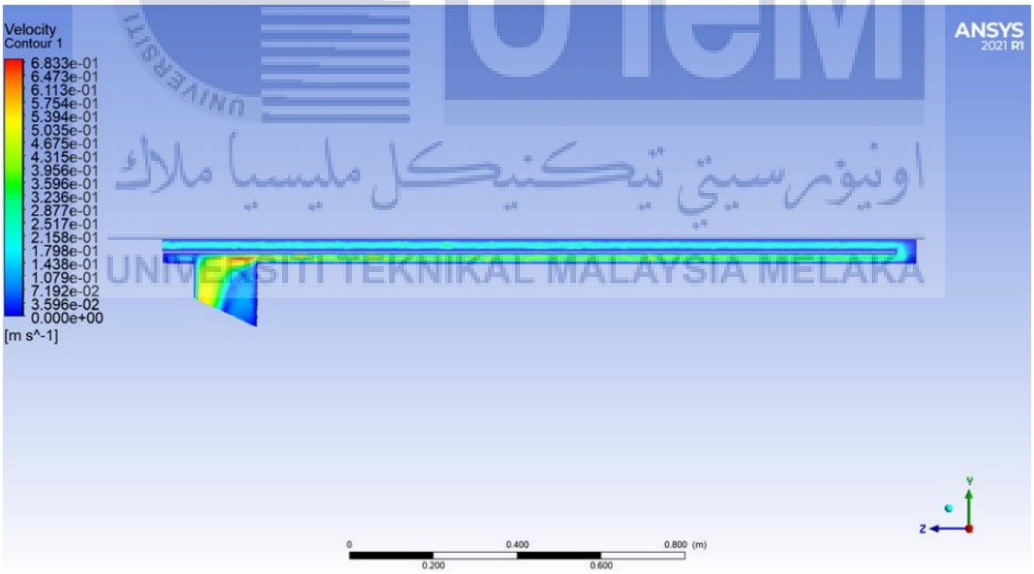

Figure 4.7 velocity of straigt fin solar collector

4.3.2 Velocity of pin fin solar collector

In a pin-fin double-pass solar collector, the airflow patterns around the fins may be better understood via velocity profiles, which in turn affect heat transfer. The increased surface area, impact air velocity, and convective heat transfer are all properties of pin fins. So, the higher velocity on this pin fin is 3.987e-01m/s. Figure 4.8 show that velocity for pin fin solar collector.

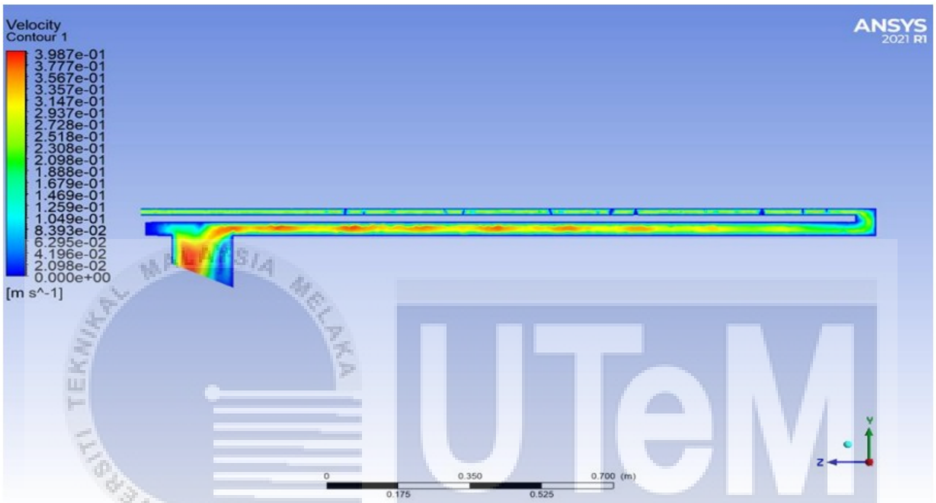

Figure 4.8 velocity of pin fin solar collector

4.3.3 Velocity of staggered fin solar collector

velocity profiles show the features of the airflow around the staggered fin arrangement of a double-pass solar collector. Staggered fins' offset placement affects air velocity, which in turn affects the collector's convective heat transfer. For staggered fin the higher velocity occur is 9.345e-01m/s. Figure 4.9 show that velocity for staggered fin solar collector.

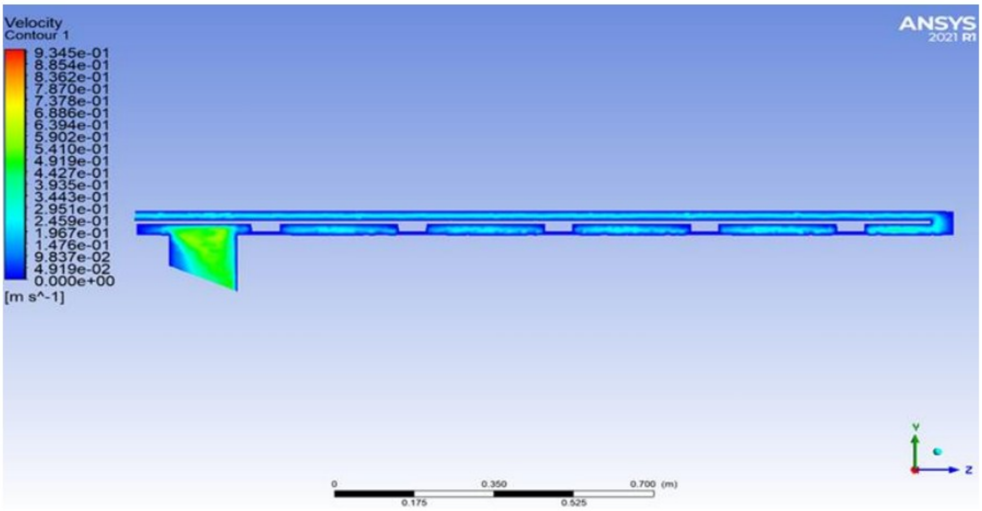

Figure 4.9 velocity of staggered fin solar collector

4.4 Pressure of solar collector

An analysis is conducted on a double-pass solar collector with several fin configurations (straight fin, pin fin, and staggered fin) to examine the effect on fluid dynamics and heat transmission by studying the pressure profiles. Various fin designs modify pressure distributions, hence impacting flow patterns and thermal properties.

4.4.1 Pressure of straight fin solar collector

The pressure profiles of a double-pass solar collector with straight fins illustrate the distribution and strength of fluid forces. Examining pressure fluctuations provides vital information on the flow patterns of air and the properties of heat transfer. Based on the result the higher pressure is 9.809e-01Pa. Figure 4.10 show that velocity for staggered fin solar collector.

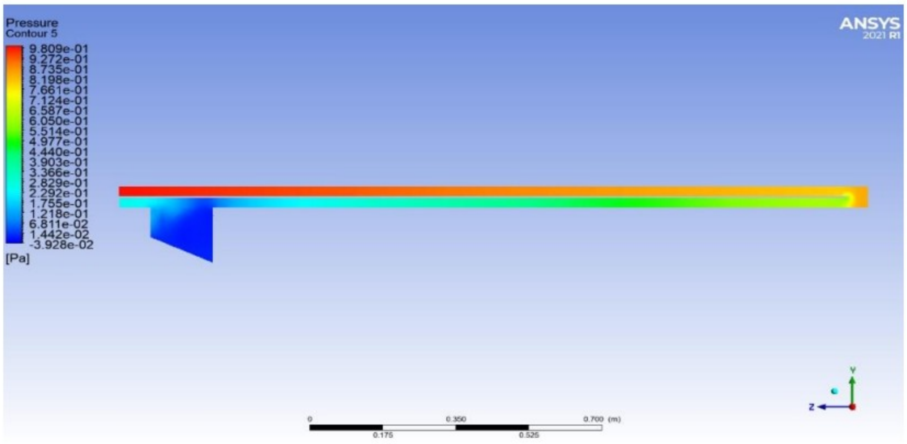

Figure 4.10 Pressure straight fin solar collector

4.4.2 Pressure of pin fin solar collector

In Ansys simulations of pin fin and straight fin shapes in a double-pass solar collector reveal clear disparities in fluid forces as shown by the pressure profiles. Pin fins, due to their larger surface area, modify pressure distributions, hence impacting airflow patterns and heat transfer properties in a distinct manner compared to straight fins. The higher pressure based on the result for pin fin is 6.410e-01Pa.

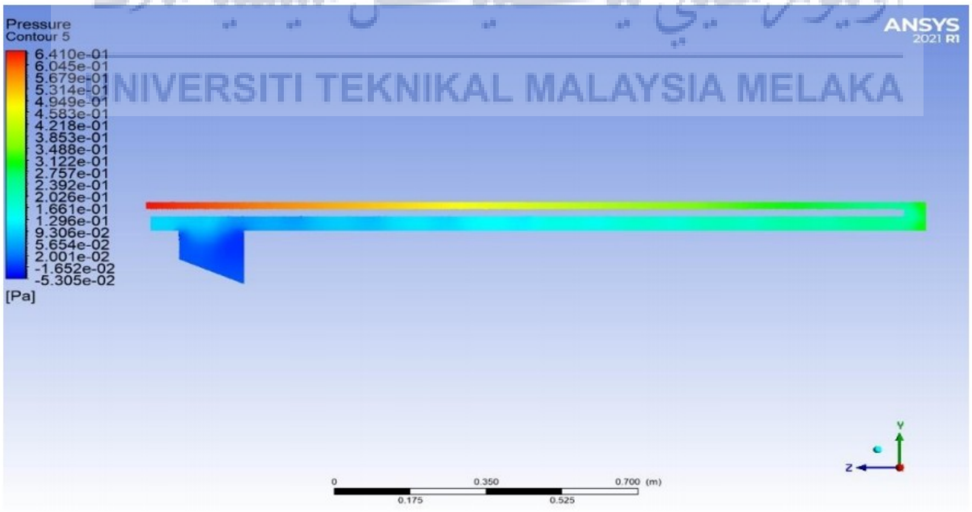

Figure 4.11 Pressure pin fin solar collector

4.4.3 Pressure of staggered fin solar collector

The variations in fluid force distributions among staggered, pin, and straight fin configurations within a double-pass solar collector are highlighted by the pressure results. The unique pressure characteristics generated by the staggered fins as a result of their offset arrangement affect airflow and heat transmission in a manner that is distinct from that of the pin and straight fins. The higher data pressure for staggered fin is 9.769e-01 Pa. Figure show that 4.12 Pressure staggered fin solar collector

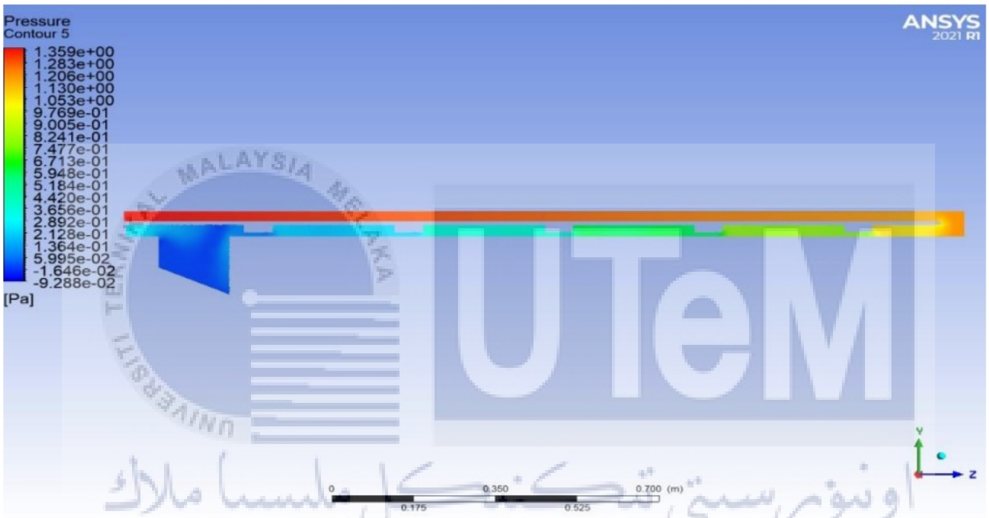

Figure 4.12 Pressure staggered fin solar collector

4.5 Discussion (graph)

The data from simulation was collected and has been ready plot a graph. This graph shows the velocities of pin fin, straight fin, and staggered fin designs as they vary with distance in a double-pass solar collector. The graph demonstrates the impact of various fin configurations on the flow of air. Table 4.1, Table 4.2, and Table 4.3 shows that value velocity and distance for straight fin, pin fin and staggered fin.

Table 4.1: Straight fin of solar collector

Velocity (m/s)	17.76	13.07	8.38	3.69
Distance (m)	0.225	0.45	0.675	0.9

Table 4.2:Pin fin of solar collector

Velocity (m/s)	9.95	7.21	4.47	1.74
Distance (m)	0.175	0.35	0.525	0.7

Table 4.3: Staggered fin of solar collector

Velocity (m/s)	24.67	18.25	11.83	5.42
Distance (m)	0.175	0.35	0.525	0.7

Based on the data, staggered fin has the highest velocity which is 24.67 m/s compared to straight fin 17.76 m/s and pin fin 9.95 m/s at the earliest distance. As it goes further downstream, the velocity drops for all fin arrangements. Thus, it is suitable to be used in solar dryer which the air can absorb the moisture from the product that needs to be dry. However, for the staggered fin arrangement, there is a huge velocity different as the solar collector output. This is because the staggered fin configuration induces changes in airflow patterns, causing variations in velocity along the collector's length. These variations could influence how heat is spread out and the effectiveness of heat transfer within the collector.

From the results, the arrangement of straight fins and staggered fins has a large velocity decrease of about 80% of the initial velocity. However, the pin fin has a constant decrease in velocity as it travels further downstream. Therefore, this arrangement is the best compared to other fin arrangements. Figure 4.13 shows the velocity versus distance graph for each array of solar collector fins.

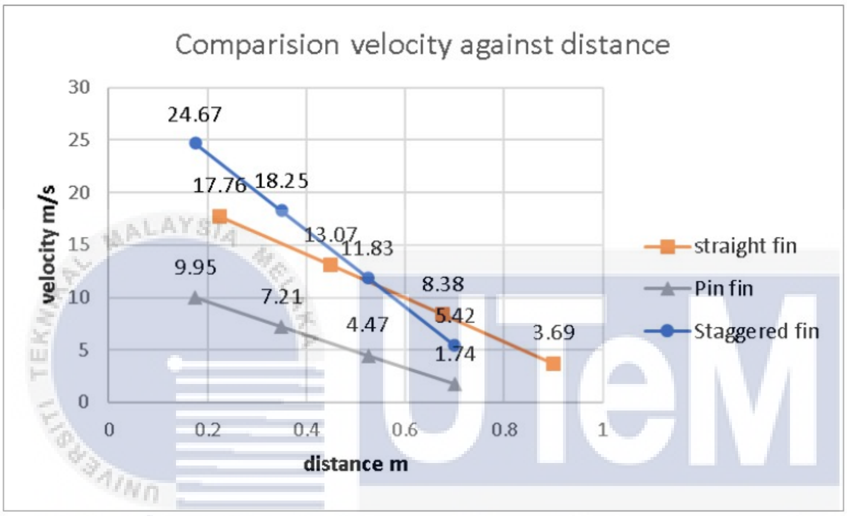

Figure 4.13 Graph velocity against distance for each fin arrangement of solar collector

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 Summary of report

This study aims to make a double-pass solar collector work better by trying out different fin designs. The goal is to generate as much energy as possible. The investigation looks closely at various fin shapes, like straight fins, pin fins, and staggered fins, in the double-pass solar collector..

Furthermore, the research aims to assess the impact of airflow behavior on the selected fin configurations in the double-pass solar collector. Gaining a comprehensive understanding of the airflow patterns around and through the fins is essential for maximizing convective heat transfer.The study seeks to gain insights into the dynamic interactions between the air and fin shape by undertaking a thorough examination of the airflow patterns. This will contribute to improving the design of the collector. The effect of fin shape on convective heat transfer is seen by these airflow patterns. Fins that are straight help with speed, fins that are pinched take use of more surface area, and fins that are staggered take advantage of offset placement. From the results, the arrangement of straight fins and staggered fins has a large velocity decrease of about 80% of the initial velocity. However, the pin fin has a constant decrease in velocity as it travels further downstream. Therefore, this arrangement is the best compared to other fin arrangements.

5.2 Work future

- Optimisation of Fin Design: Investigate making the straight, pin, and offset fin shapes even better. Changes in fin length, width, and spacing, among other physical variations, should be investigated to improve total collector performance and improve convective heat transfer.

- Examine the accuracy of computational fluid dynamics (CFD) outcomes by comparing them to empirical data collected from a tangible prototype. By doing so, the simulation outputs will be more credible, and the expected airflow behaviour will be confirmed under real-world conditions.

- Enhance the optimisation of fin design by investigating further improvements in straight, pin, and staggered fin designs. Examine other geometric alterations, such as modifications in the length, thickness, and spacing of fins, in order to maximise convective heat transfer and improve the overall efficiency of the collector.

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APPENDICES

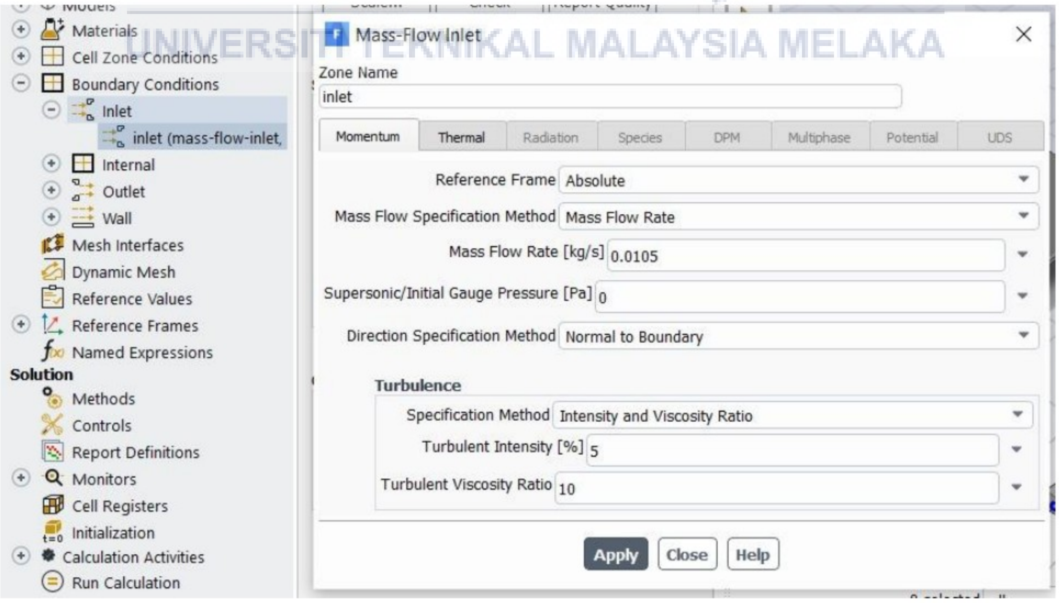
APPENDIX A: Gantt Chart

No	Week Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	PSM title registration	■													
2	PSM1 briefing	■													
3	Briefing on project title with supervisor	■													
4	Report writing of Literature Review		■	■											
5	Correction of Literature Review				■	■	■								
6	Report writing of Introduction							■	■						
7	Correction of Introduction								■	■	■				
8	Report writing of Methodology										■	■			
9	Correction of Methodology											■	■		
10	Submission of First Draft Report												■		
11	Correction of First Draft Report												■	■	
12	Submission of Final Draft Report														■

APPENDIX B: Gantt Chart

No	Week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	PSM 2 briefing with academic	■													
2	Project briefing with supervisor.	■													
3	Making design of the product		■	■											
4	Learning Ansys fluent simulation			■	■	■									
5	Meshing product				■	■	■	■							
6	Start making simulation Air flow						■	■	■	■					
7	Identify the problem of simulation								■	■	■				
8	Correction of Methodology										■	■			
9	Making a flow chart of the studies											■	■		
10	Report writing						■	■	■	■	■	■	■		
11	Making poster													■	
12	Presentation preparation														■

APPENDIX C: Boundry Condition 1



Mass-Flow Inlet

Zone Name: inlet

Reference Frame: Absolute

Mass Flow Specification Method: Mass Flow Rate

Mass Flow Rate [kg/s]: 0.0105

Supersonic/Initial Gauge Pressure [Pa]: 0

Direction Specification Method: Normal to Boundary

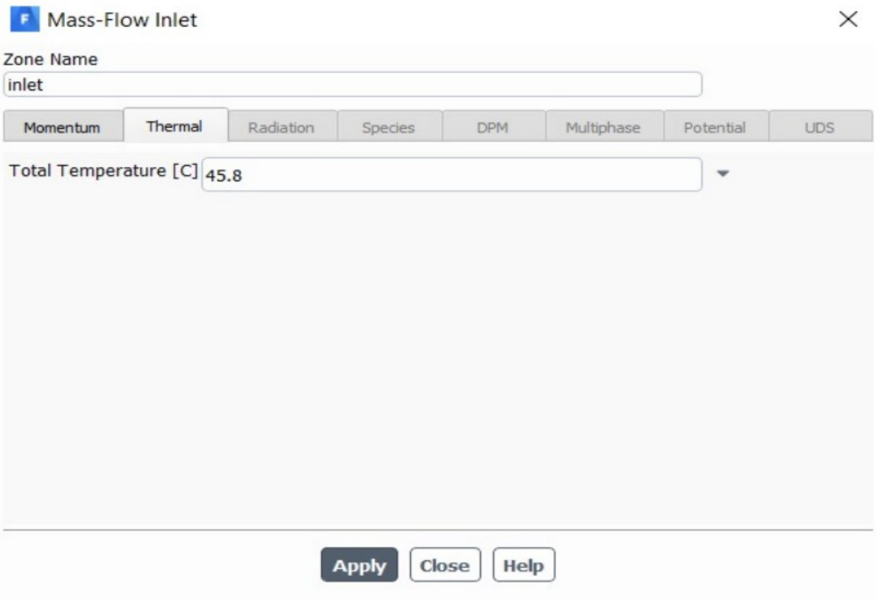
Turbulence

Specification Method: Intensity and Viscosity Ratio

Turbulent Intensity [%]: 5

Turbulent Viscosity Ratio: 10

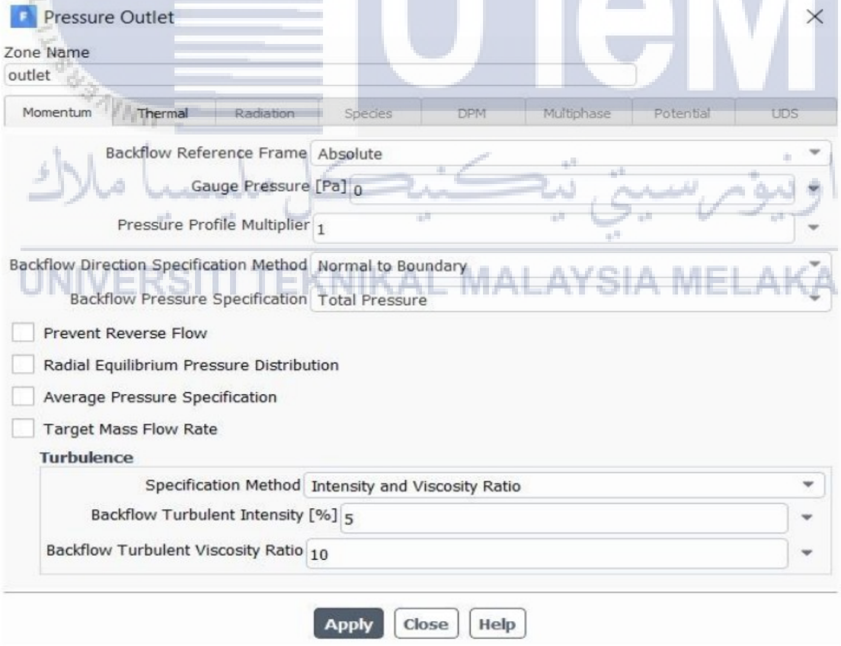
APPENDIX D: Boundry Condition 2



Zone Name: inlet

Total Temperature [C]: 45.8

APPENDIX E: Boundry Condition 3



Zone Name: outlet

Backflow Reference Frame: Absolute

Gauge Pressure [Pa]: 0

Pressure Profile Multiplier: 1

Backflow Direction Specification Method: Normal to Boundary

Backflow Pressure Specification: Total Pressure

☐ Prevent Reverse Flow

☐ Radial Equilibrium Pressure Distribution

☐ Average Pressure Specification

☐ Target Mass Flow Rate

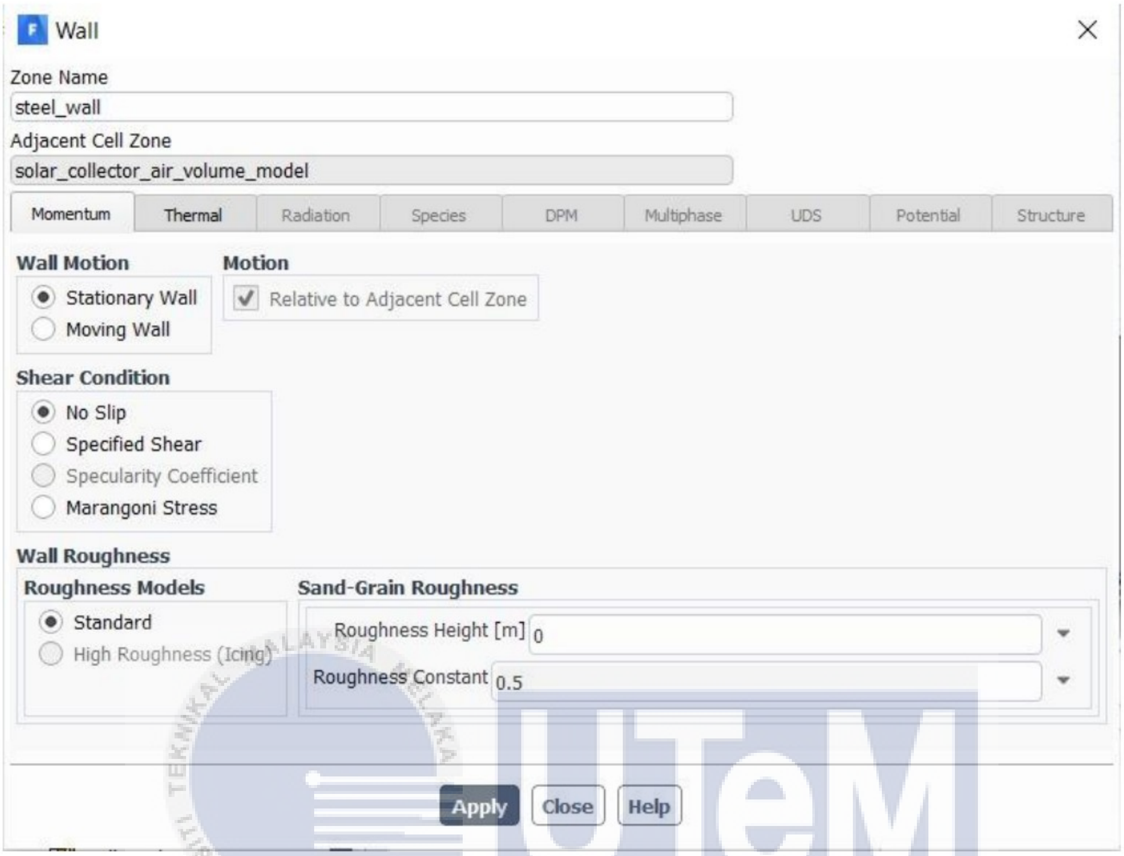
Turbulence

Specification Method: Intensity and Viscosity Ratio

Backflow Turbulent Intensity [%]: 5

Backflow Turbulent Viscosity Ratio: 10

APPENDIX F: Boundry Condition 4



Zone Name
steel_wall

Adjacent Cell Zone
solar_collector_air_volume_model

Wall Motion
● Stationary Wall
○ Moving Wall

Motion
☑ Relative to Adjacent Cell Zone

Shear Condition
● No Slip
○ Specified Shear
○ Specularity Coefficient
○ Marangoni Stress

Wall Roughness

Roughness Models
● Standard
○ High Roughness (Icing)

Sand-Grain Roughness
Roughness Height [m] 0
Roughness Constant 0.5