REPUBLIC OF TURKEY

BARTIN UNIVERSITY

GRADUATE SCHOOL

DEPARTMENT OF MECHANICAL ENGINEERING

MASTER'S THESIS

PERFORMANCE ANALYSIS OF AN AIR SOLAR COLLECTOR WITH EXTENDED HEAT TRANSFER SURFACE AREA WITH PLATE FIN GEOMETRY

PREPARED BY

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BARTIN-2023

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ACCEPTANCE AND APPROVAL

DECLARATION

I hereby declare that, this master’s thesis prepared in accordance with Bartın University Graduate School thesis writing manual, conducted under the supervision of Assoc. Dr. Abid USTAOĞLU and titled “PERFORMANCE ANALYSIS OF AN AIR SOLAR COLLECTOR WITH AN EXTENDED HEAT TRANSFER SURFACE FIELD WITH PLATE BLADE GOMETRIC” is a unique study, all information has been obtained in accordance with academic rule and ethical conduct. I have fully cited and referenced all material and results that are not original to this work and that I will accept any legal sanctions if found otherwise.

08.12.2022

Zeyad Raed AMJED

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Thank you.

Zeyad Raed AMJED

ÖZET

Yüksek Lisans Tezi

LEVHA KANATÇIK GEOMETRİ İLE GENİŞLETİLMİŞ ISI TRANSFER YÜZEY ALANINA SAHİP BİR HAVALI GÜNEŞ KOLLEKTÖRÜ PERFORMANS ANALİZİ

Zeyad Raed AMJED

Bartın Üniversitesi
Lisansüstü Eğitim Enstitüsü
Makine Mühendisliği Anabilim Dalı

Tez Danışmanı: Doç. Dr. Abid USTAOĞLU

Bartın-2023, sayfa: 58

Günümüzde enerji tüketiminin büyük bir kısmı kömür, petrolden ve doğalgazdan sağlanmaktadır. Bunlar sera gazı seviyesinde artış, küresel ısınma ve çevre kirliliği gibi birçok probleme sebep olmaktadır. Daha fazla ülkenin karbondioksit emisyonlarını azaltma taahhütlerini yerine getirebilmeleri için, yenilenebilir enerji payının dünyanın enerji arzının çoğunu oluşturacak şekilde artırılması gerekmektedir. Bu yakıtlara alternatif olarak güneş enerjisinin büyük bir potansiyeli bulunmaktadır. Yeryüzüne gelen bir saatlik güneş radyasyonu, tam bir yıl boyunca küresel enerji ihtiyacını karşılamaya yetecek kadar bir enerji sağlar. Türkiye güneş enerjisinden sıcak su elde eden güneş kolektörlerini yoğun bir şekilde kullanmaktadır. Ancak mekan ısıtmada kullanım çok sınırlıdır. Havalı güneş kollektörleri güneşten gelen ışınlar ile içinden geçen havayı ısıtan bir çeşit ısı değiştiricidir. Bu sistemlerde havaya olan ısı transfer hızı sıvıya oranlara daha düşük olduğundan bu eksikliği ortadan kaldırmak için ısı transfer yüzey alanının artırılması gerekmektedir. Yapılacak tezde öncelikli olarak havalı güneş kollektör tasarımı yapılacak ve hava akışını sağlayabilecek şekilde dizayn optimize edilecektir. Yüzey alanının artırılması için bir radyatör kullanılacaktır. Bu radyatör hava akışını engellemeyecek şekilde lazer ile veya su jeti ile uygun boyutlarda kesilecek ve güneş kollektör tasarımına uygun hale getirilecektir. Elde edilen sistemin tasarımı yapılıp daha önce belirlenmiş olan havalı güneş kollektör geometrisine adapte edilecektir. Elde edilen radyatör geometriler kollektörün hava akışı boyunca belirli bölgelerine yerleştirilecektir. Elde edilen yüzey alanı artırılmış havalı güneş kollektörünün CFD analizi yapılacaktır. Bu analizlerde radyatörün yerleştirilme açısı, radyatör sayısı gibi birçok parametrenin sistem performansı üzerindeki etkisi incelenecektir. Tasarlanan havalı güneş kollektörünün üretimi yapılacaktır. Gerekli malzemeler tedarik edilip sistem oluşturulacaktır. Hava akışı bir fan yardımı ile yapılacaktır. Sistem çeşitli hava koşullarında, çeşitli radyatör konum, açı ve sayılarında test edilecektir. Ayrıca kollektör yüzey siyah boya ve seçici yüzey boyası ile kaplanarak bu kaplamaların etkisi ayrıca incelenecektir. Son olarak sistem optimizasyonu yapılıp radyatör geometri ile yüzey alanı genişletilmiş havalı güneş kollektörü ekonomik yönden incelenecektir. Tasarlanan yüzey alanı genişletilmiş havalı güneş kollektörü ile düşük maliyetli ve daha verimli bir sistem üretilmesi amaçlanmaktadır. Böylece bireysel kullanıma uygun hale gelecektir. Güneş enerjisinin evsel veya mekansal ısıtma amacıyla kullanılması sağlanacaktır. Güneş enerjisinin yeterli olduğu yerde yakıt maliyetini ortadan kaldıracak yetersiz olduğu yerde ise yakıt maliyetinin azalmasına katkıda bulunacaktır

Anahtar Kelimeler: Havalı güneş kollektörü, radyatör, ısı değiştirici, güneş enerjisi, ekonomik analiz

Bilim Alanı Kodu: 92802

ABSTRACT

M. Sc. Thesis

PERFORMANCE ANALYSIS OF AN AIR SOLAR COLLECTOR WITH EXTENDED HEAT TRANSFER SURFACE AREA WITH PLATE FIN GEOMETRY

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Today, most of the energy consumption is provided by coal, oil, and natural gas. These cause many problems such as an increase in greenhouse gas levels, global warming, and environmental pollution.

For more countries to meet their commitments to reduce carbon dioxide emissions, the share of renewable energy needs to increase to account for most of the world's energy supply. Solar energy has great potential as an alternative to these fuels. An hour of solar radiation coming to the earth provides enough energy to meet the global energy needs for a full year. Turkey intensively uses solar collectors that generate hot water from solar energy. However, its use in space heating is very limited. Air solar collectors are a kind of heat exchanger that heats the air passing through it with the rays coming from the sun. Since the heat transfer rate to the air is lower than the ratio to the liquid in these systems, it is necessary to increase the heat transfer surface area to eliminate this deficiency. In the project to be done, primarily the air solar collector design will be made and the design will be optimized to provide airflow. A radiator will be used to increase the surface area. This radiator will be cut in appropriate sizes by laser or water jet in a way that will not prevent airflow and will be made suitable for the solar collector design. The design of the obtained system will be made and adapted to the previously determined air solar collector geometry. The resulting radiator geometries will be placed in certain parts of the collector along with the airflow. CFD analysis of the air solar collector with the increased surface area will be made. In these analyzes, the effect of many parameters such as the placement angle of the radiator and the number of radiators on the system performance will be examined. The designed air solar collector will be produced. The necessary materials will be procured and the system will be established. Airflow will be done with the help of a fan. The system will be tested in various weather conditions, at various radiator positions, angles and numbers. In addition, the collector surface will be coated with black paint and selective surface paint, and the effect of these coatings will be examined separately. Finally, the system will be optimized and the air solar collector with an expanded surface area with radiator geometry will be examined economically. Thus, it will be suitable for individual use. Solar energy can be used for domestic or space heating. Where solar energy is sufficient, it will eliminate the fuel cost, and where it is insufficient, it will contribute to the reduction of the fuel cost.

Keywords: Air solar collector, radiator, heat exchanger, solar energy, economic analysis.

Scientific Field Code: 92802

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LIST OF SYMBOLS AND ABBREVIATIONS

H_b	: The global radiation includes direct
H_d	: Diffuse Solar Radiation
ϕ	: the latitude the of the location
ω	: the hour angle of the sun
δ	: the declination angle
ψ	: zenith angle
A	: azimuth angle
s	: tilt angle
α	: Elevation angle
ρ_r	: describes effective diffuse
β	: the inclination angle
η_{opt}	: indicates the optical efficiency
U_{SAH}	: the total heat transfer
T_{sky}	: the temperature of glass cover
ε	: the emissivity of the glass cover
η	: Efficiency
η_{th}	: energy efficiency
η_{ex}	: exergy efficiency
D_h	: the equivalent hydraulic diameter

ABBREVIATION

SAH	: Solar Air Heater
FSAH	: Fin solar Air Heater
TASAH	: Tilt Angle Solar Air Heater
RE	: Renewable Energy
ERS	: Renewable energy Sources
IEA	: World Energy Outlook
CSP	: Content Security Policy
PV	: Photovoltaic
GEPA	: Güneş Enerjisi Potansiyel Atlası
Re	: Reynolds number
Nu	: Nusselt number
C	: Collector

1. INTRODUCTION

1.1 Energy

Energy is defined as the ability of a system to produce an external action. Energy is the fundamental building component that forms the foundation of every person's daily activities and is important to a sustainable quality of life. Energy is crucial for social and economic growth & development. In this sense, energy is separated into mechanical energy (that is, potential or kinetic energy), main, and secondary energy sources according to their conversion into energy. Primary energies are hard coal, lignite, crude oil, natural gas, hydraulic power, geothermal energy, solar energy, and are utilized through conversion. Energy sources are divided according to their composition into traditional (non-renewable) and renewable energy.

1.1.1 Global Energy Problems

Today, the energy demand is increasing due to factors such as industrialization, technological development, and population growth. For these reasons, energy is seen as the most important problem worldwide. The energy problem was no longer a local problem, became a global problem and began to guide international politics. The fossil-based energy pool, which we call conventional energy sources, makes up about 90% of the energy in use today. Fossil-based energies such as coal, oil, natural gas, and uranium (nuclear energy) are not as clean and inexhaustible as renewables. It is known that these resources will of course run out one day. While there are many technological applications powered by fossil fuels today, when it is believed that these energy sources will run out one day, countries will be greatly affected by this crisis, primarily economically. In addition to the economic effects of the global energy problem, it also causes environmental problems due to the environmental damage it causes. Most of the environmental pollution we see today is caused by fossil fuels. The harmful gases emitted as a result of the use of fossil fuels not only harm human health but also cause environmental pollution. This environmental pollution arises in the shadow of major environmental problems such as rising water temperature, which we call global warming, the emergence of acid rain, the depletion of the ozone layer, and the effect of greenhouse gases.

1.2 Renewable energy sources

When events such as global warming, the global oil crisis occur, and also geographical conditions, greater environmental consciousness, and restricted usage of fossil fuels, the relevance of renewable energy sources grows and the trend towards this sector is cited as essential. Renewable resources are characterized as solar, geothermal, hydraulic, wind geothermal, biomass, wave, and non-fossil sources of energy. (DURSUN, 2019).

Renewable energy (RE) is also described as a production of energy that may be produced from natural sources and continually renews itself, since it can renew itself automatically and does not perish, unlike other forms of energy. In addition, because renewable energy sources are ecologically favorable local resources (cutting carbon emissions), there is no need to import them. For this reason, it is particularly significant in terms of minimizing foreign dependency on energy and safeguarding the environment. (Ismail Kavaz, 2017) .

In the hunt for energy resources, there have been situations such as disparities in the geographical distribution of fossil resources, and greater dependency on foreign sources due to the absence of particular resources in some nations. Although it may appear pricey at first when it comes to investment fees in this industry, this cost will pay for itself as it may be utilized for many years. For this, it is expected that sufficient investments may be made by offering an improved technical system, cutting prices, and giving the required incentives, therefore the usage of renewable energy will expand. In this approach, renewable energy sources will lessen dependency on foreigners instead of conventional sources and will become a livable energy source in the long run. (Cihan, 2019).

The RES (Renewable Energy Sources) capacity in the globe is constantly expanding every year. It is said that the expansion in the number of nations benefitting from renewable energy also minimizes environmental losses and motivates them to satisfy their energy demands from renewable energy sources in the future (REN21, 2020: 48). (REN21, 2020: 48). Figure 1.1 illustrates the entire growth in final power output from renewable energy globally.

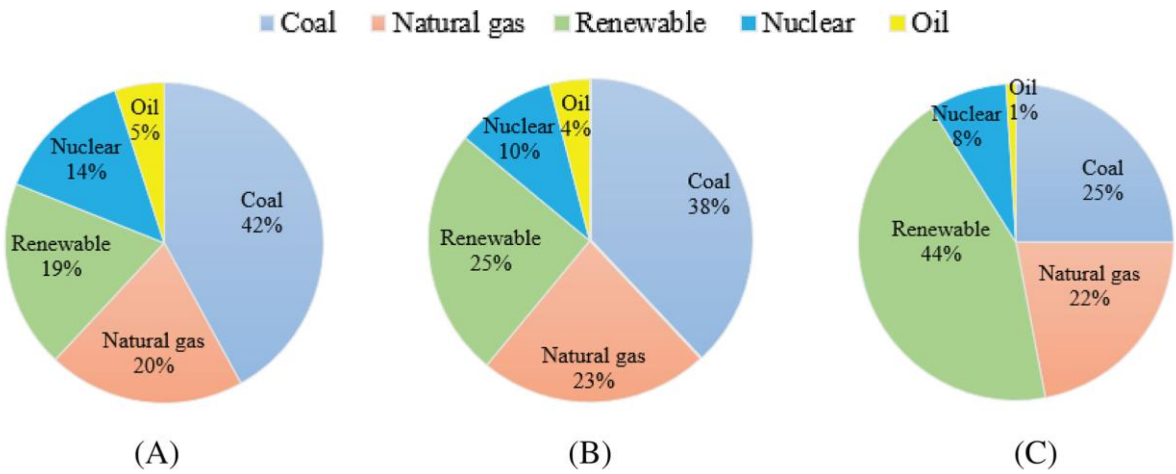


Figure 1.1: World primary energy sources for electricity generation (A) for the year 2010 (B) for the year 2017 (C) stated policies for the year 2040 (Energy Agency, 2021)

1.2.1 Wind energy

It is claimed that owing to the heating of the earth by the sun's rays, the temperature difference between the oceans and the air generates a pressure differential so that winds are generated that induce the flow of air to get electrical or mechanical energy (Erdem & Kadir, 2015).

Obtaining energy from wind energy is gained by systems that convert the kinetic energy of the airflow, i.e. wind, created from an area of high pressure to a zone of low pressure, first into mechanical energy and subsequently into electrical energy. conversion into useable energy. The mechanical energy gained is transmitted to the gearbox and then to the generator via the shaft and transformed into electrical energy (Özden et al., 2015.)

Wind energy, which was utilized for grain processing and sea transport by sailing ships for so many years, is now employed to create electricity (Hayli, 2001)

1.2.2 Biomass energy

It is described as compounds produced from organic matter, that is, from all-natural materials of plant and animal origin, and which have an energy component. Energy derived from biomass using different technological techniques is termed bioenergy.

Although fossil energy sources like oil, natural gas, and bioenergy originate from the same source, the most essential distinction between them is that bioenergy is acquired from living creatures.The source of this energy, which is stored chemically, especially in the form of cellulose, during the photosynthesis processes of plants and then used in various forms, is the sun. The conversion of solar energy into stored energy in the form of biomass is essential for human life (Özsabuncuoğlu & Uğur, 2005). Plant resources, animal waste, industrial waste having biological structures, and urban trash in the environment in which we live are claimed to constitute bioenergy .

While bioenergy is acquired, it is obtained in the form of solid, liquid, and gas fuels (biogas, biomethane, biohydrogen, etc.), typically power, heat, and transportation. Can be utilized in the fields. Today, soybeans and maize grain (used to make ethanol) are the two most popular nutrients utilized for biomass fuels (for biodiesel). Plans for the long future include growing and using quickly expanding trees and specific energy crops like grasses and mosses (Mohtasham, 2015)

1.2.3 Hydropower energy

The mechanical energy of hydropower was employed by water mills around 2000 years ago, and with the evolution of technology, the potential energy of water was turned into kinetic energy in hydroelectric power plants. It is said that it is still used as a form of FE. Since the state of electrostatic power plants fluctuates with seasonal events such as water flow rate and flow rate. Hydroelectric power, like other energy sources, is first acquired by transforming the potential and kinetic energy of water at a given height to mechanical energy using a turbine and then transformed into electrical energy utilizing a generator attached to the generator. Turbine shaft (Şekkeli & Keçecioğlu, 2011).

Hydraulic energy, like some other renewable energies, gives a benefit in terms of making use of existing resources without affecting the environment (Oral, 2017)

Though it still takes natural gas a step further, the fact that there is no fuel expense and extended working life, no danger, no air pollution, and readily acquired energy is stored, makes hydraulic power effective versus coal and natural gas.

1.2.4 Geothermal energy

The geothermal resource is defined as the Earth's heat, which includes hot water, steam, and gases containing compounds that come from heat stored at various depths of the Earth's crust, is what is referred to as a geothermal resource. Geothermal springs typically develop close to volcanic units, rocks, and active rifting systems. An example of renewable energy is geothermal energy, which is produced by the heat of magma deep in the ground and radioactivity in rocks. Fluids in fissures or fractures in the Earth's crust transport heat to the Earth (Kiliç F & Kiliç M, 2013). Depending on the source temperature, geothermal energy may be used for a variety of purposes, including heating, power production, producing hot water for drinking and other uses in industry and health tourism (Erkul, 2012).

1.2.5 Wave energy

Sea or ocean waves The surface of a sea that's also imbalanced as a consequence of the varied warmth of the earth's surface as a result of external effects such as wind, vehicle movement in the sea, earthquakes beneath the sea, or the gravitational pull of the moon. Sea waves created by the impact of wind are continuous compared to the water waves formed by forces other than wind, and hence are considered to be predominantly taken into consideration in energy acquisitions (ÖRER et al., 2003).

Wave energy is the most advocated form of energy for sustainable technology. Only the most significant and trustworthy energy source is wave energy, which is more dependable than many renewable energy sources. Although wave power has a 90% power, it cannot be compared to solar and wind energy in terms of pace. This form of energy is simple, keeps the ecosystem in balance, is affordable, pure, and clean. It also has no negative environmental effects. The possibilities of technology make it simple to get wave energy, an energy source that benefits the nation's economy (Kapluhan, 2014).

1.2.6 Hydrogen Energy

Hydrogen is colorless and odorless but does not occur freely in nature. It is more prevalent like water and is frequently in a complex form. While providing energy from hydrogen, numerous sources of energy such as water, fossil fuels, and biomass are utilized. As a consequence of extracting energy from hydrogen, hazardous gases that exacerbate the greenhouse effect are not emitted into the environment.

Several methods such as electricity, thermoelectric processes, waste gas purification, radiological analysis, photovoltaic processes, and vapor recovery are employed in hydrogen generation (Tutar & Mehmet, 2011). hydrogen; may be used for heating and energy production, and hydrogen can also be employed as raw resources and fuel for an engine (Haşimoğlu et al., 2000).

1.2.7 Tidal energy

Tidal currents are the rising and falling of the oceans as a consequence of the gravitational pull that the Moon and the Sun exert on the Earth. Electricity production from tidal energy is the act of converting kinetic energy to produce electrical energy via a turbine by taking advantage of differences in height and reduction in mass of water displaced during tidal movements (Leyla Honça, 2018).

1.2.8 Solar energy

The Sun was a vital, necessary and unlimited source of energy for living creatures on Earth. In bringing natural occurrences such as the water cycle, wind, and photosynthesis from educating the world to warming it, it sits immediately at the base of all energy sources.
Indirectly, as the oldest and most important source of energy. For example, increasing temperatures in various parts of the planet caused the production of winds owing to pressure differences, creating wave energy in the seas and oceans, making the sun a significant component and a necessary source of energy from the past to the present (Akusta, n.d.).
Solar energy is a sort of energy created by the conversion (fusion) of hydrogen gas in the sun's core into helium, which is thermal energy. Electrons are created from sunlight by photovoltaic systems and technologies, and the resultant electrons are collected and transformed into high-voltage solar panels that are suited for environmental circumstances and may be utilized in power production facilities (KILIÇ, 2015). There are two major types of solar energy generation today: electricity and thermal energy production. The sun benefits in 2 different ways as a result of technological advancements: photovoltaic cells (or solar cells) are solar panels and systems made of crystalline silicon and otherwise various thin semiconductor materials that convert sunlight to electricity, & solar thermal technologies, that use water and air by collecting heat from the sun's cycles or conventional steam (Çetin et al., 2019).

1.3 Structure of the Sun

The Sun is a massive star with a diameter of 1,392,000 kilometers and a mass 333,000 times that of the Earth (Christensen-Dalsgaard, 2021).

Outside the earth's atmosphere, the density of solar energy is defined as 1370 W/m2. Because of the atmosphere, only 0-1100 W/m2 of this number reaches Earth. The Sun and the Earth are 150 million kilometers apart. The energy that the sun provides to the planet is 20,000 times that which the world consumes yearly. Because of the structure of the atmosphere, 50% of solar energy reaches the Earth, 30% is refracted, and 20% is trapped in the atmosphere and clouds (GEPA, 2008).

The solar system radiation transmission is shown in (Fig 1.2), in which the nearly spherical Sun distributes its energy evenly in all directions. The Sun's surface temperature is about 6000 Kelvin, while its core temperature is between (8-40) x 106 K. The sun emits around 4 x 1023 kilowatts per second of radiative energy. Radiation from the sun takes 8 minutes to arrive on our planet. The energy received by the Earth from sunlight in 40 minutes is equivalent to the entire energy used in the globe in a year. Every four weeks, the sun turns. The equator takes 27 days to complete this revolution, whereas the poles take 30 days. The Sun's average concentration is 1409 kg/m3, whereas our world's average concentration is 5517 kg/m3. The Sun's gravitational acceleration is 273.98 m/s2, while our world is 9.81 m/s2. In the sun, the quantity of helium produced is less than the amount of hydrogen consumed. The difference is what gives the sun's beams their energy. In one sec, 564 million tons of hydrogen transform into 560 million tons of helium in the Sun's core. 386 x 106 EJ of energy released into space as a consequence of the fusion process in the Sun's core (Extra Joule). 1 EJ is equal to 22.7 million tons of oil. Because the conversion of hydrogen to helium is expected to continue for another 5 billion years, the Sun may be considered an everlasting source of energy for our planet (F. Dincer, 2011).

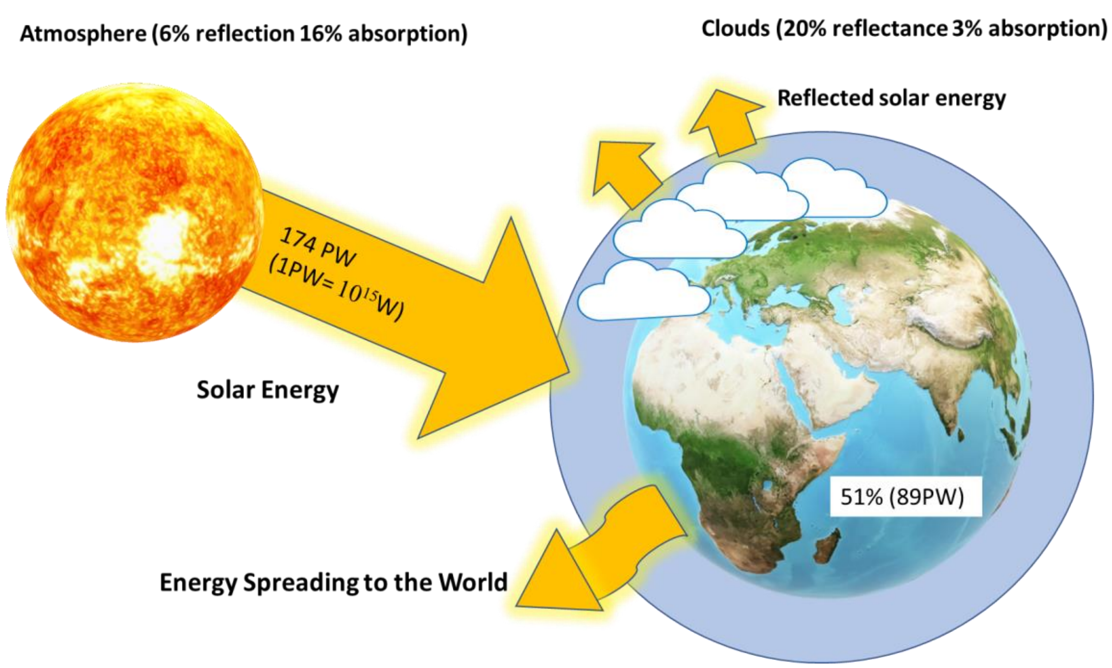


Figure 1.2: Solar system radiation transfer (Abid Ustaoglu, 2014)

1.3.1 Sun Angles

It is vital to know the sun's angles. Let's take a quick look at the angles created by the sun's beams on the Earth's surface and other surfaces so we can make better use of solar energy.

1.3.1.1 Latitude Angle (φ):

The angle of latitude is the angle formed by a line from the location on the Earth to the Center of the earth intersecting the equatorial plane.

1.3.1.2 declination angle (δ):

is the angle formed by the rays of the sun and the equatorial plane. The deviation angle is between -23,45º ≤ δ ≤ 23,45º. On March 21 and September 21, the slope angle is 0º, as illustrated in Figure 1.3. Cooper's formulais used to compute the value. The number "n" represents the number of days since January 1st.

$$\delta = 23.45 \sin\left[360.\left(\frac{(284+n)}{365}\right)\right] \tag{1}$$

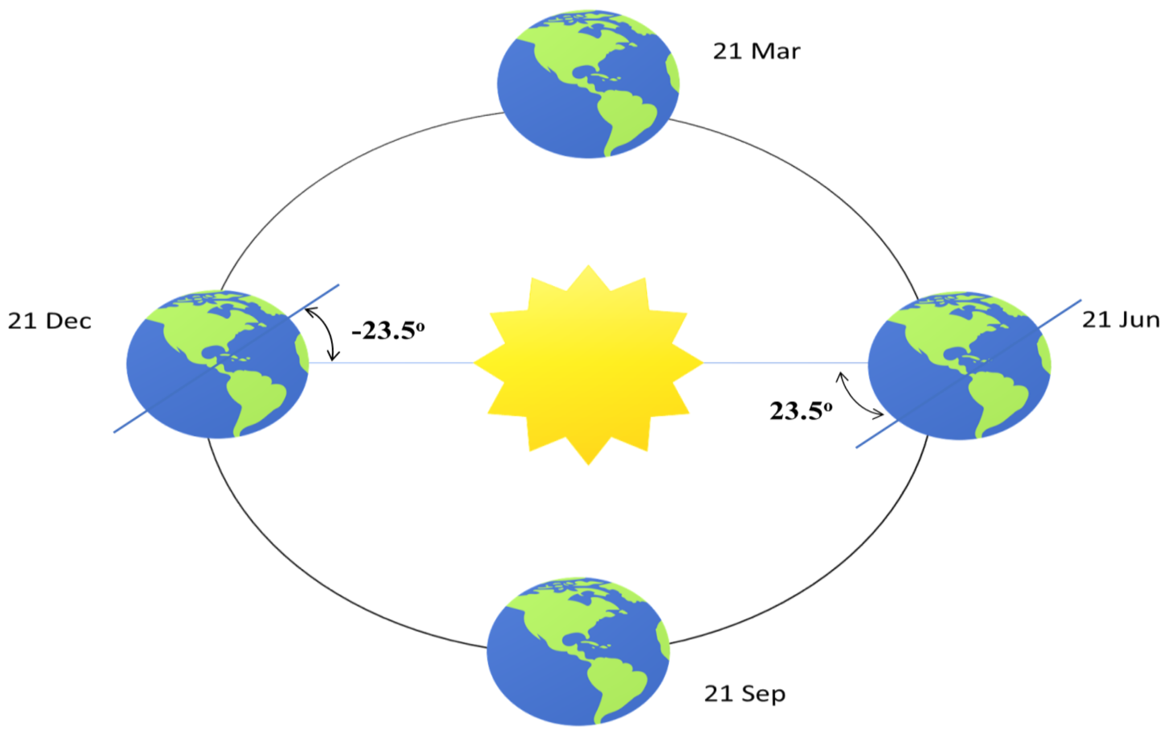


Figure 1. 3: Declination angle(Shivalingaswamy & Kagali, 2017)

1.3.1.3 Zenith angle (ψ): It's the angle formed by the horizontal plane's vertical plane and the sun's beams. The azimuth angle is 0 when the sun's rays strike the Earth perpendicularly. The maximum angle is 90 degrees at dawn and dusk. The sun's angles are depicted in Fig. 1.4

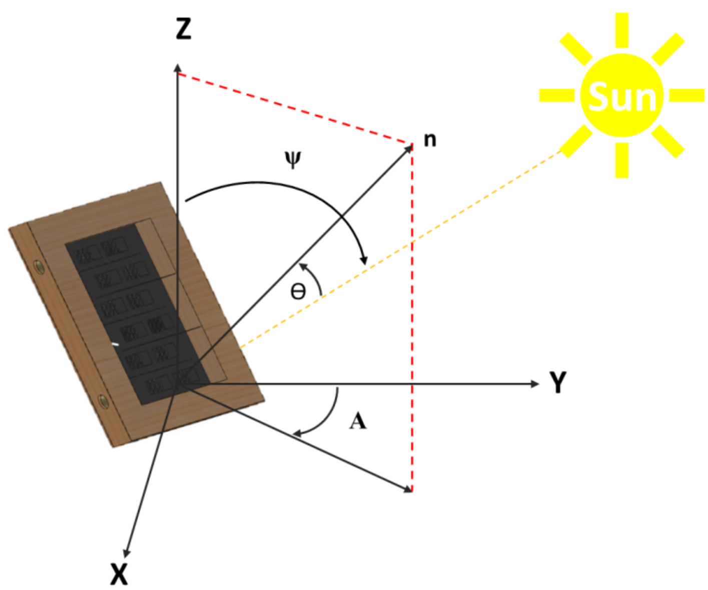


Figure 1.4: Sun angles (Lovegrove & Stein, 2012)

1.3.1.4 Azimuth angle (A): It's the angle formed between the north-south direction and the inclined surface's normal plane. The south is 0 degrees, the west is 90 degrees, the east is -90 degrees, and the north is 180 degrees. The azimuth angle is shown in Figure 1.5

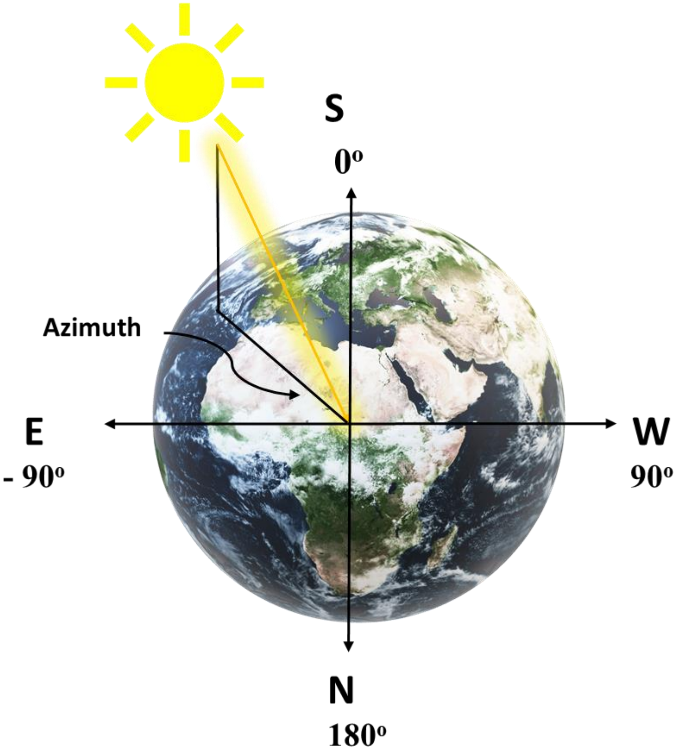


Figure 1.5: Definition of the sun's Azimuth angle

1.3.1.5 Tilt angle (s): The angle that an inclined plane makes with the horizontal.

1.3.1.6 Sun incidence angle (θ): is the angle formed by the sunrays striking the collector's plane in relation to the plane's natural plane.

1.3.1.7 Elevation angle (α): is the le that the sun's rays make with the horizontal plane.

1.3.1.8 Hour angle (ω): The angle formed between the longitude of the sunrays and the location's longitude. One hour equals 15 ° longitude.

1.4 The wavelengths of sunlight

The ultraviolet, visible, and infrared wavelengths of sunlight that reaches the Earth are all present. The wavelengths of the sun's beams range from 200 nanometers to 2,400 nanometers when they reach the Earth. The energy distribution spectra of solar radiation are shown in Figure 1.6.

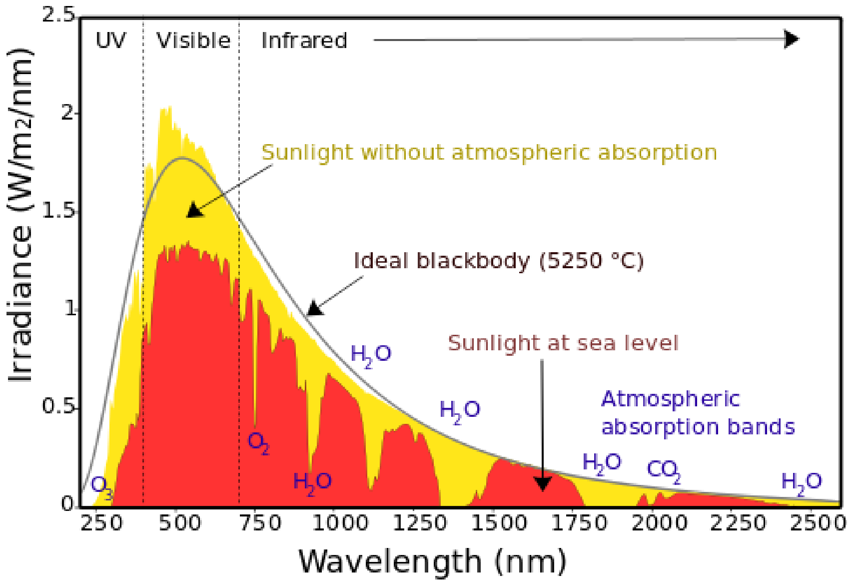


Figure 1.6: Energy distribution spectra of solar radiation (Şenay, 2011)

1.4.1 Ultraviolet-UV Rays (200-400 nm)

The location of these rays is separated into three sections and investigated.

1. The region of the atmosphere where rays absorbed by the ozone layer are unable to flow through, with wavelengths ranging from 200 to 280 nm.

2. The region of the atmosphere where rays absorbed by the ozone layer are unable to flow through, with wavelengths ranging from 280 to 320 nm.

3. The portion where rays with wavelengths ranging from 320 to 400 nanometers travel through the atmosphere and reach the Earth.

1.4.2 Visible Rays (400-750 nm)

This visible color zone is similarly separated into three pieces and investigated.

1. Rays in the purple-green hue spectrum have a wavelength of 400-520 nm.

2. Rays in the green-red color spectrum have a wavelength of 520-620 nm.

3. The rays in the red color spectrum have a wavelength of 620-750 nm.

1.4.3 Infrared Rays (750-2400 nm)

1. The region in which near-infrared photons with wavelengths ranging from 750 to 1400 nm are found.
2. The region in which mid-infrared photons are found and the wavelength is between 1400-2000 nm.
3. The region where far-infrared radiation with wavelengths between 2000 and 2400 nm is found.

1.5 Solar Energy Systems in the World

Solar energy in the planet, as previously stated, is the massive amount of energy released by the Sun's fusion processes that reach the Earth. By investing more in renewable energy sources rather than exploiting the world's natural resources, countries that have achieved considerable technical development benefit from cleaner, cheaper, and unlimited energy supplies.

Solar panels may be used to generate electricity in skyscrapers, cultural buildings, and any other place where they can be used in the developed world. They save money by employing clean energy instead of harming the environment in this manner. Countries that use renewable energy sources like solar are developing at a quicker and more demand-driven pace. They are beginning to apply these technologies in solar-powered automobiles, street lighting, solar cells, and heating and cooling systems, for example. When we look at the world's usage of solar energy, we compare it to European nations, particularly the United States. China leads the way in terms of regions of usage and nations receiving the most sunshine; the majority of Africa, Australia, and the central part of the Americas get the greatest solar radiation.

Germany, Denmark, China, and Spain are among the world's major solar energy producers; in terms of solar energy production and technology, these countries may be regarded pioneers in Europe and even the globe. With its technological and industrial might, Germany is on the verge of becoming a worldwide force. Despite having a lower rate of sunbathing than other nations, it is one of the countries that has achieved significant development in solar energy systems. On the other hand, according to the size of the world map (Fig. 1.7), Turkey has yearly solar radiation of between 1500 and 2000 kWh per square meter, indicating that we are a nation that is above the global average.

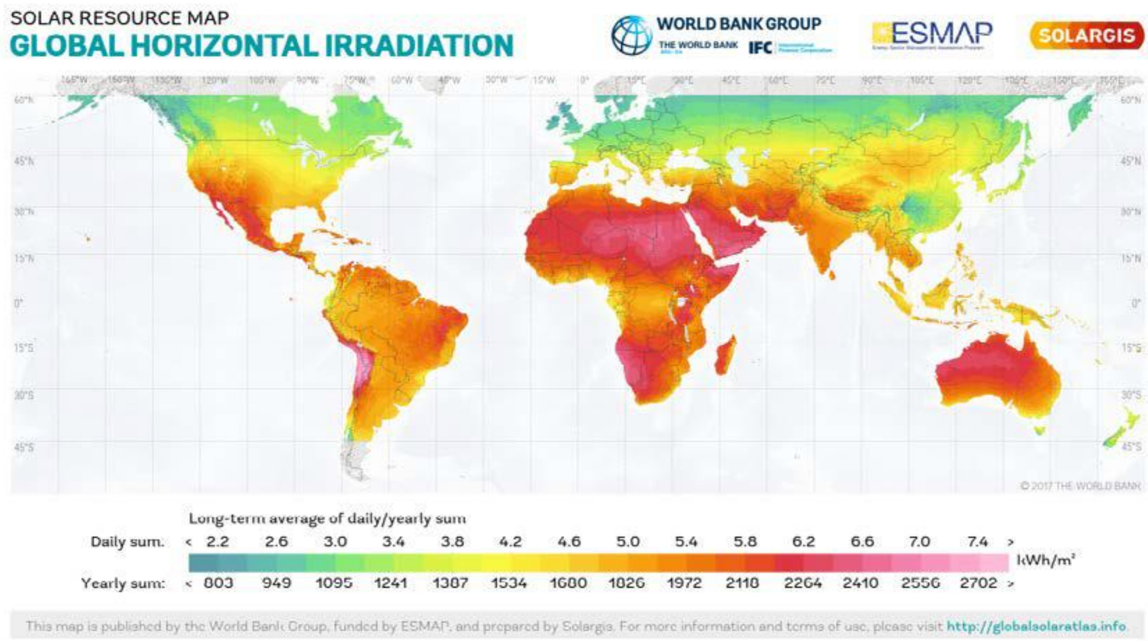


Figure 1.7: Sunbeams On Earth's Surface (Suri, 2019)

1.6 Solar Energy Presence in Turkey

Solar energy, like other forms of renewable energy, is very important. Despite the fact that Turkey, like the rest of the globe, lags in solar energy systems, major investments and research are being done. Our nation is in a fantastic position to reap the benefits of solar energy. Due to its geographical position, Turkey's solar energy potential is quite acceptable. Regrettably, despite its enormous potential, a clean and renewable energy source remains mostly untapped. Solar energy technologies are becoming more important in Turkey. While Turkey is making remarkable achievements in the energy sector, infrastructure for solar energy systems are being constructed. Because even states with high rates of sunbathing have tremendous access to these systems, whereas our nation has a low rate of sunbathing. Figure 1.8, which depicts the seasons of sunshine in Turkey, will be used to estimate the various conditions. Our southern areas, which are bigger than our northern parts, get the most sunshine on a yearly basis, followed by the Mediterranean region, as indicated on the map. According to statistics from the Turkish Power Transmission Corporation (TEIAş, 2006), In turkey yearly electricity output is 97686.3 (Gigawatt-hours). Solar energy is employed in a variety of applications, including hot water production, heating, lighting, and power generation. Solar energy systems are classified into two categories based on these applications.

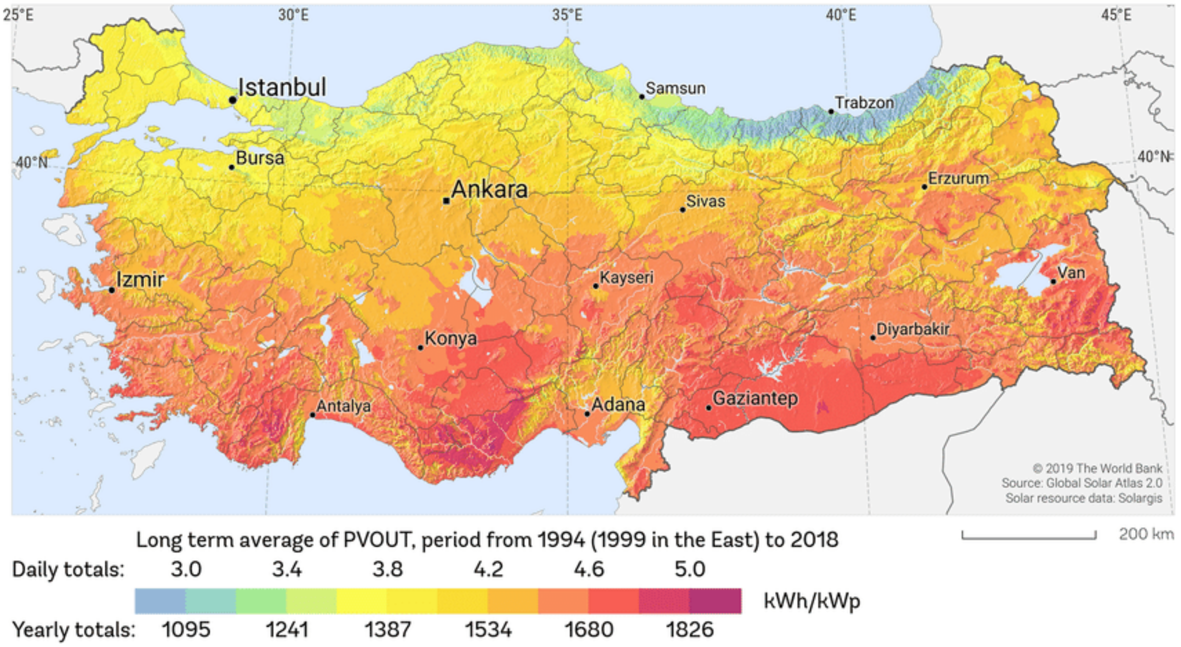


Figure 1.8: Turkey solar energy map(Zateroğlu & Kandırmaz, 2018)

Annually, around 110 days of solar energy are consumed in the figure. In terms of monthly solar potential, July had the greatest value of about 175 (kWh/m^2-year). Every year, an average of 2,640 hours of sunshine are collected.

Tablo 1.1: Monthly Average Solar Energy Potential of Turkey (Varınca & Gönüllü, 2006)

Months	Monthlıy Total Solar Energy		Insolation Duration	Months	Monthlıy Total Solar Energy		Insolation Duration
	(Kcal/cm^{2}M)	(kWh/m^{2}M)	(H/M)		(Kcal/cm^{2}M)	(kWh/m^{2}M)	(H/M)
JAN	4,45	51.75	103.0	AUG	13.62	158.40	343.0
FEB	5.44	63.27	115.0	SEP	10.60	123.28	280.0
MAR	8.31	96.65	165.0	OCT	7.73	89.90	214.0
APR	10.51	122.23	197.0	NOV	5.23	60.82	157.0
MAY	13.23	153.86	273.0	DES	4.03	46.87	103.0
JUN	14.51	168.75	325.0	TOTAL	112.74	1311	2640
JUL	15.08	175.38	365.0	AVERAGE	308.0 Cal/cm^2-D	3.6 kWh/m^2-D	7.2 H/D

Turkey's most vibrant area. In terms of energy, Southeast Anatolia is the wealthiest area in our nation, followed by the Mediterranean area. Table 1.2 shows the results. The total yearly incoming solar energy for this area is 1,460 (kWh/m^2-year), with 2,993 hours of sunlight per year. Aside from that, Turkey's Black Sea area has the lowest solar potential. As a result, Turkey's total yearly energy consumption is 1015 kWh.

Tablo 1.2: Distribution Solar Energy Potential by Regions (Varınca & Gönüllü, 2006)

Regin	Total Solar Energy (kWh/m^2-year)	Sunshine Duration (Hour/year)
Southeastern Anatolia	1,460	2,993
Mediterranean	1,390	2,956
Eastern Anatolia	1,365	2,664
Central Anatolia	1,314	2,628
Aegean	1,304	2,738
Marmara	1,168	2,409
Black Sea	1,120	1,971

1.7 Solar Energy Technologies

Solar energy is assessed in a variety of ways utilizing active applications since it is a clean, unlimited, and plentiful source of energy. Solar energy is utilized for two purposes: heating and generating power. Heating, cooling, drying, distillation, power production, and so on are all examples of solar energy. Thermal technologies that convert it into heat energy for different applications have been developed, as have technologies that convert it directly into electrical energy using photo-electric material(Çeçen et al., 2022) .

It must first supply sunlight absorption in ordeto from the sun's energy. Indirectly, this process occurs in two ways: thermally and electrically (electro-photovoltaic). Thermal techniques are more often employed because of their simplicity and inexpensive cost, but as technology improves, the photovoltaic approach has become the favored option. Thermal solar collectors are classified into three categories: (1) low, (2) medium, and (3) high. Photovoltaics transform photons of light energy into electrical energy called photoelectricity by electrically collecting sunlight (Sen et al., 2018).

We may see many various approaches, equipment, and tactics utilized in practice if we look at the research that has been done to profit from solar energy. in Fig 1.9 Let's attempt to group togethety of ways and technologies under the umbrella of solar energy.

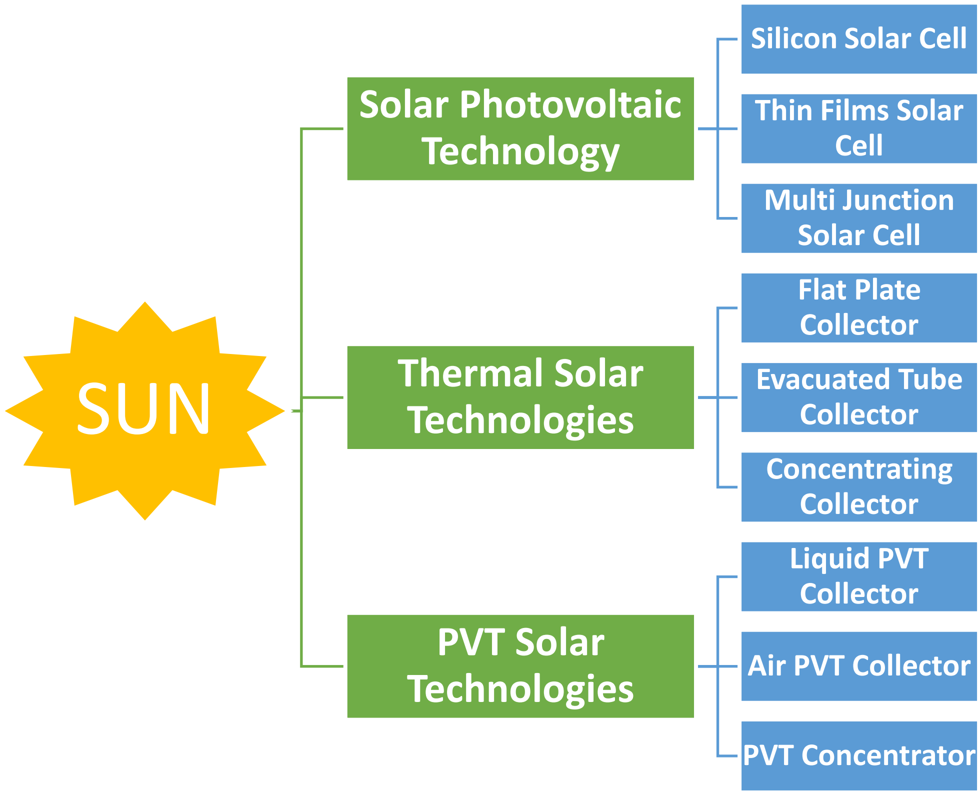


Figure 1.9: Types of solar technologies.

1.8 Literature Review

Sabzpooshani vd., (2014) presented the effect of different fin coefficients, glass cover thickness, bottom insulation thickness, and inlet air temperature at different mass flow rates on energy efficiency. It was found in the study that installing blades and baffles at low mass flow rates had a positive result in energy efficiency, but showed an opposite result at higher mass flow rates.

Abo-Elfadl et al., (2020) evaluated the recirculation of the air under the absorber plate to draw some of the air over the absorber plate and then remove more heat from the absorber plate. The results showed that the temperature of the absorber plate decreases with increasing the rate of top airflow.

Priyam & Chand, (2016) evaluated the system consisting of two undulating blades on an absorber plate and a thermally insulated bottom side. It has been found that the use of wavy fins increases the heat transfer surface area and the heat transfer coefficient. Increasing the airflow rate from the solar air heater has been found to not only result in higher efficiency but also an increase in pressure drop.

Wijeysundera et al., (1982) evaluated whether the double-glazed operation of the solar air heater in two-way mode is an inexpensive way to increase collector efficiency. The performance of the collector was checked under the design and operating conditions and it was found that the two-lane designs outperformed the one-way system by about 10-15%.

El-Sebaii et al., (2011) experimentally and theoretically investigated the thermal performance of a double-glazed solar air heater with a bed-pack layer on the heater absorption plate. Limestone and gravel were used as bedding pack material. In order to increase the outlet temperature of the air after sunset, it has been proposed to use low porosity high mass bedding packaging materials. Gravel has been shown to perform slightly better than limestone.

Bhushan & Singh, (2010) made investigations to increase the rate of heat transfer to the air flowing in the duct of a solar-powered air heater. In the results, the artificially roughened absorbent plate surface was considered to be an effective technique. Various roughness geometries were evaluated to examine the heat transfer and friction properties of an artificially roughened duct in solar air heaters. It has been observed that artificial roughness is a good technique to improve the thermal performance of solar air heaters.

Kumar & Chand, (2018)Consider the thermal and thermohydraulic performance of an expanded surface absorbent solar air heating collector equipped with twisted splices with a twist ratio of Y=2, 4, 6, and 8. In the research, it was determined that the collector with fins and absorber plate attached with twisted bands with Y=2 twist rate was the most efficient.

Dissa et al., (2016) designed and tested a solar air collector with a composite absorber. The composite absorber is formed by combining a non-porous absorber made of corrugaa ted iron sheet and a porous absorber made of aluminum mesh. The results showed that the overall thermal efficiency of the collector at noon was approximately 61%, with maximum temperatures of 77, 142, 107, and 73 °C for the glass cover, non-porous and porous absorbers, and airflow, respectively.

Abdullah et al., (2018) experimentally investigated the performances of the new double double-pass air heater with and without a turbulator in their research. Aluminum cans are attached to the upper and lower surfaces of the absorber plate and used as a turbulator to increase the heater efficiency. Three differently designed absorber plates were tested for DPSAH: (a) a flat-plate absorber without cans, (b) absorbent r with cans in a staggered configuration, (c) and a third containing cans arranged in a staggered configuration. Aluminum cans create turbulence density in the flow area and enlarge the heat transfer area of DPSAHs, and therefore it was used to increase the heat transfer rate. The results showed that the maximum daily efficiency for graded DPSAH was 68% at 0.05kg/h.

Naphon., (2005), numerically investigated the performance and entropy production of a double pass flat plate solar air heater with longitudinal fins. The mathematical models described the heat transfer properties of the double pass flat plate solar air heater derived from the energy conservation equations. The effects of the inlet conditions of the working fluid and the size of the solar air heater on the heat transfer characteristics, performance, and entropy generation are considered. It has been determined that as the fin height and number increase, the thermal efficiency increases. In order to ensure the novelty of this study, a literature review was conducted and it was determined that there were no similar publications according to the results obtained.

MesgarPour et al., (2021), the writers of this article in which the energy efficiency and heat transfer performance of a double pass solar air heater with helical flow path (HFP) were experimentally and mathematically studied in a triangular cross-section channel. The findings of this research were created by referring to the grid independency and validation of the earlier work of the authors. Finally, the impacts of triangle section angles and diameters and the placement of the entry section of each channel were explored and optimized. The findings revealed that optimized geometry resulted in a much superior thermo-hydraulic performance as compared with reference geometry for all Reynolds numbers which demonstrated a minimum increase of t 16.5 percent following optimization. The inactive vortices created at the margin of entry flow passage were lowered in each channel owing to optimization which also dropped the pressure drop.

Heydari & Mesgarpour., (2018), carried out a numerical and experimental investigation of a solar air heater with a helical flow path and a triangular cross-section channel. The heat transfer coefficient and thermal efficiency were calculated with two different flow rates. The average thermal efficiency of double pass SAH with the helical design was 14.7% higher compared to the simple one and about 8.6% higher than the double pass-finned plate.

Hassan & Abo-Elfadl., (2018), conducted an experimental analysis of a tubular type of solar air heater (SAH). The tubular type of the solar air heater as compared to a flat type one with the same dimensions and materials. The tubular one provides higher efficiency, thermal power, and lower heat losses.

Yeh & Lin., (1996), explored the influence of collector size on the efficiency of air-heated solar collectors when the air flow is above the black surface, both experimentally and conceptually. In this study, they show that increasing the collector volume (L/D) enhances efficiency by around 10% and that the efficiency of the collector where air flows from the top of the absorber plate is 18% greater than that of the collector where air flows under the black surface.

Ertekin & Bilgili., (1998), utiliseutilizedated solar energy.They pr ovided formulae for heat acquisition factor, efficiency factor, and total heat loss coefficients used in measuring thermal efficiency by introducing collectors and providing information regarding absorbing surfaces, permeable coverings, insulating materials, and sheaths used in their construction.

Türk toğrul & Pehlivan., (2002), The effect of the position of the absorber surface on the thermal efficiency of dual-air heated solar collectors. The influence of various absorbent surfaces on the thermal performance of a newly designed conical condensing air heater with filler material in a double-pass airflow duct was explored in this study. Standard black-coated copper tubes were used for this purpose, and the selective surface was determined to have the maximum thermal efficiency when compared to the industrially coarse adsorption.

Alvarez et al., (2004), evaluated the efficiency of a single-pane pneumatic solar collector with an absorbent surface consisting of aluminum circular recycling bins. Theoretical temperature values were compared with the experimentally obtained temperature values.

They discovered that a pneumatic fluid solar collector built with circulation boxes has a greater efficiency rating.

Abene et al., (2004), investigated the influence of air duct blockages on collector performance. They noted that various criteria, such as the size, shape, orientation, and position of impediments, have an effect on the collector's efficiency.

Forson et al., (2003), created a mathematical model of a double-bored single-pass solar-antenna complex. They demonstrated that using the model collector, the values of solar radiation, heat transfer coefficient, average air flow rate, and average temperature produced successful results. They claimed that by selecting proper collector features and channel depth with two air gaps from top to bottom, they could obtain a considerable performance gain in dual-cavity, single-pass liquid-air solar collectors. They also demonstrated that changing the air mass flow rate affects efficiency.

Karim & Hawlader., (2006), tested the heating of a 13-square-meter space in winter using a solar air collector. They increased indoor temperatures by 5 to 20 degrees Celsius by using liquid-pneumatic sun collectors.

Esen., (2008), A flat tflat-typee-flow collector's energy and exergy analyses were experimentally compared with and without obstructions on the absorber surface. Repeated experiments were conducted with various absorber surface types and fluid flow rates. The efficiency values of the double-flow collector with an obstruction on the absorber surface have been found to be higher than those of the flat type collector, according to the experimental results.

Kurtbas & Durmuş., (2004), performed comparisons between collectors with four different types of selective surface shapes and planar collectors by comparing their energy efficiency and exergy. They discovered that the shape of the absorber surface had an impact on how much heat transferred and how much pressure was lost.

1.9 Purpose of the study

Today, most energy consumption is provided by coal, oil, and natural gas. These cause many problems such as increasing the level of greenhouse gases, global warming, and environmental pollution. Global energy use is increasing rapidly as living standards rise for billions of people in the developing world. For more countries to meet their commitments to reduce carbon dioxide emissions, the share of renewable energy must be increased to cover most of the world's energy supply. Solar energy has great potential as an alternative to these fuels. An hour of solar radiation coming to Earth provides enough energy to meet global energy needs for an entire year. Solar collectors, which produce hot water from solar energy, are widely used. However, its use in space heating is very limited. Solar air collectors are a type of heat exchanger that heats the air passing through them with rays from the sun. Since the rate of heat transfer to air is less than the rate of heat transfer to liquid in these systems, it is necessary to increase the heat transfer surface area to eliminate this deficiency. This study aims to conduct an empirical study of the effect of adding geometry of radiator consisting of large surface area fins on the performance of the solar collector to increase the amount of heat transfer in the solar air collector. By reviewing the literature, it turns out that this is the first time that work has been done on an extended surface solar collector with radiator geometry. The main objective of the thesis is to design a low-cost and high-efficiency solar air collector. It is intended to make a substrate for collecting solar energy without losing heat to the environment. For this, the inner and outer surface temperatures will be measured and the amount of loss can be determined. In addition, they are intended to reduce heat loss from the surface of the glass. Therefore, double glazing and single glazing systems will be evaluated. Depending on the amount of incoming solar energy, it will be possible to measure how much energy is lost. It aims to design a system that is more efficient than a standard wind-solar collector. For this, the new system with both standard geometry and coolant geometry will be examined experimentally and numerically. Thus, it will be possible to measure the improvement in system performance. In the system, it aims to examine the effect of selective surface coatings on improving performance. For this purpose, standard black paint and selective surface paints will be used. Thus, performance improvement can be measured. The effect of different weather conditions on system performance will be examined. For this, tests and measurements of the system will be carried out under different atmospheric conditions. It is intended to determine the optimal angles and positions of the radiator geometry. For this, the geometry of the radiator will be evaluated under the same conditions by placing it at different angles and positions.

2. SOLAR ENERGY COLLECTORS

Solar collectors capture sunlight and store it in liquid or air.

When it comes to solar collectors, they are separated into two categories based on the heat transport fluid.

1-Liquid collectors.

2-Air collectors.

2.1 Solar Collectors Type

Heat exchangers that travel through the body. They are divided into four categories:

1- Flat surface solar collectors.

2- Solar collectors of the concentrator type.

3- Vacuum solar collectors.

4- Air solar Air collectors.

2.1.1 Flat surface solar collectors

Flat plate collectors are typically made up of a transparent cover, and energy collecting surface, heat transporting pipes, insulating material, and a casing that keeps all of the components together. Figure 2.1 depicts its structural kinds.

The transparent cover reflects some of the solar energy into the environment, while the absorber surface absorbs the rest. The absorber surface absorbs the majority of the energy that hits it, and part of it is reflected as long wavelength radiation towards the transparent cover. Some of the reflected radiation on the transparent cover is reflected to the absorber surface, while the rest travels through the transparent cover and into the environment. The heated absorber's surface energy is mostly transferred to the carrier fluid. Through transmission and transit, some of it travels from the safe medium to the environment . In most cases, collectors are used to heating domestic hot water. They attain a temperature of about 70 degrees Celsius. Swimming pools, industrial facilities, and houses all utilize these systems to produce hot water.

2.1.2 Solar collectors of the concentrator type

The parabolic trough collecting technique is the most common form of technology used in Content Security Policy (CSP) systems. Depending on the size and configuration of the solar collecting region, a certain size and number of parabolic pool collectors may be built-in CSP facilities using parabolic pool collectors. (Altuntop & Erdemir, 2013). Solar energy is focused into a black absorber tube that passes through the collector's focus by reflective surfaces within the collector. To collect energy, the liquid is cycled through the absorbent tube. The collected heat is used to create energy at the power plant. These systems may attain even greater temperatures as a result of condensation. (350-400°C).

2.1.3 Vacuum solar collectors

The performance of vacuum tube solar collectors is superior to that of other related collector designs. One explanation for this is because borosilicate (Pyrex) glass holds heat rather of transmitting it immediately. It is made up of tubes and has a vacuum layer between the two layers within the pyrex. A vacuum-like that of a thermos may hold up to 93 percent of thermal energy, resulting in increased efficiency.

2.2 Air solar collectors

One of the most basic instruments for turning solar energy into thermal energy is air solar collectors. A permeable glass or plastic cover, an absorbent plate, tubes or ducts built into or put under the plate, insulating material, and a casing are all common components. The absorbent plates that absorb incoming solar energy and transmit it to the working fluid are the most significant component of these collectors.

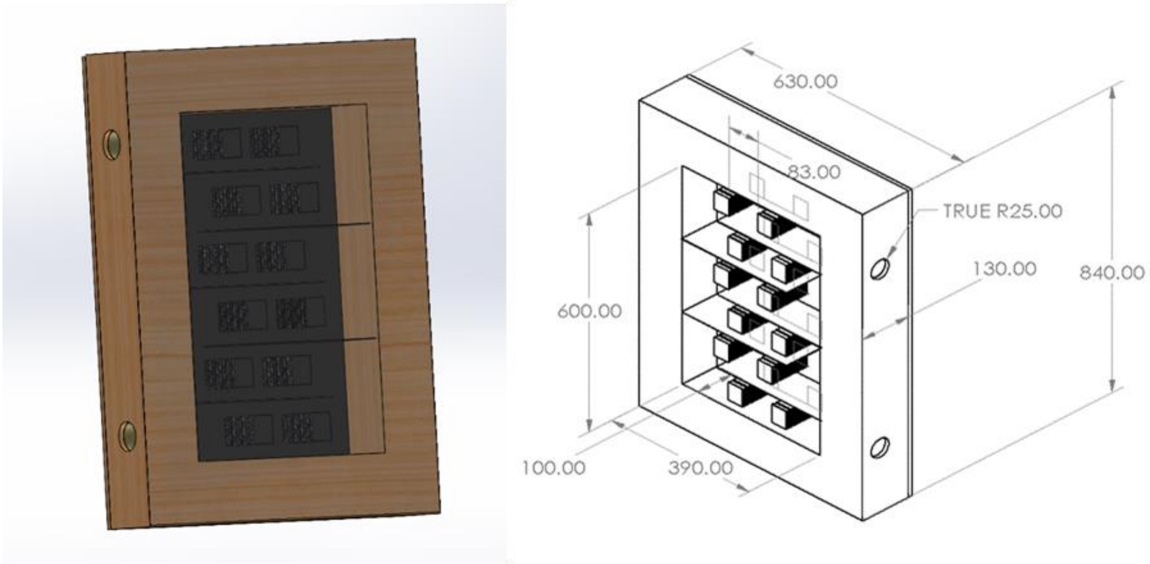
2.3 Solar air heater

Solar energy is clean energy and may be utilized without damaging the environment. Solar energy is utilized to create electrical energy in two ways via solar thermal techniques and photovoltaic methods. Photovoltaic (PV) conversion is a well-known method for converting energy directly from sunlight into electrical energy. Solar Air Heaters Solar air heaters are an essential way of utilizing solar energy and may find use in various activities that need low and medium temperatures. A solar collector is an easiest and cheapest technique to convert solar energy into thermal energy by collecting heat from sunlight. A traditional solar air heater normally comprises an absorbent plate with a parallel plate beneath that provides a channel with a high aspect ratio through which the air to be heated flows. A transparent cover system is given around the absorbent plate, while a sheet metal container packed with insulation is provided at the bottom and sides. Several sun collectors are available for thermal energy conversion depending on operating temperature requirements. Solar collectors are the essential component in a solar water heating or air heating system and the major categorization of solar collectors is deconcentrated and concentrated collectors. Solar collectors utilize the energy they create to transform the energy they receive from solar radiation into hot air and transmit the energy flowing from the collector. The job of the solar collector is extremely straightforward. It shields the sun and turns it into useable energy that may suit your present demands. Solar heaters are the cheapest and most extensively used equipment owing to their small weight. The major downside of a solar therapist is the requirement to monitor the air. There are two fundamental drawbacks to traditional solar air heaters. The first is that the heat transfer from a metal plate to the air is quite weak since the air conductivity is low. The second difficulty is related to the combined impact of limited heat transmission from the plate to the air and the relatively tiny thickness of the absorbent plate. This may be rectified by expanding the heat transfer area via the use of fins, the solar air heater is simple in construction and needs minimal maintenance. Conventional solar panel heating systems do not operate owing to the poor coefficient of heat transfer between the plate carrier and the carrier fluid (air). In addition, because the liquid does not freeze, the solar air heater has the benefit that it does not need any extra care at temperatures below O ° C. The concerns of corrosion and leaking are also less significant.

2.4 System Design

2.4.1 Case of Solar Air Collectors

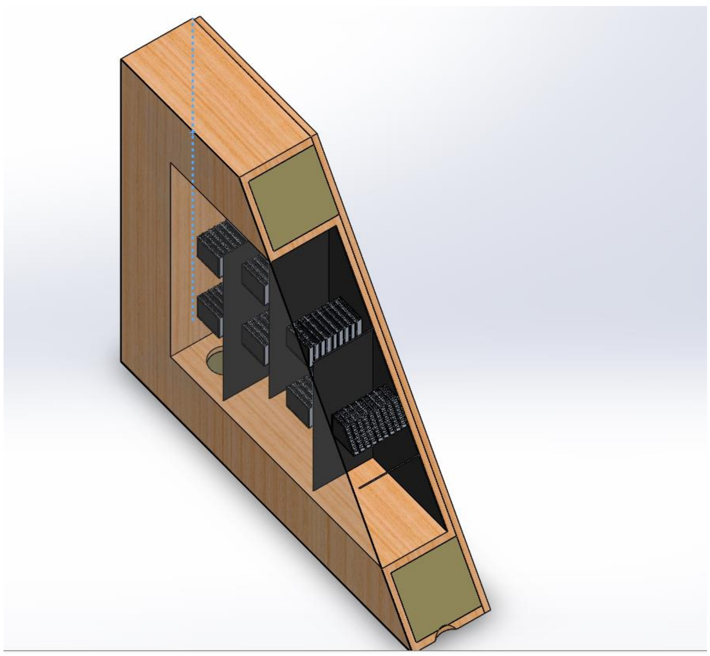
In air collectors, the case material is composed of wood with a thickness of 130 mm and The Dimensions 840*630 mm. The robustness of the safe sets it apart from others. It should be scaled appropriately. It must carry out responsibilities such as transport, protection, and thermal insulation. The box's bottom is lined with an aluminum plate. (See Figure 2.1) The dimensions of the materials used in the complex's construction are determined without taking into consideration thermal expansion, which has certain negative repercussions. Especially if the aluminum plate's elongation isn't taken into consideration.



Figuer 2.1: The Case of Solar Air Herter System

2.4.2 Insulation in The Air Collector

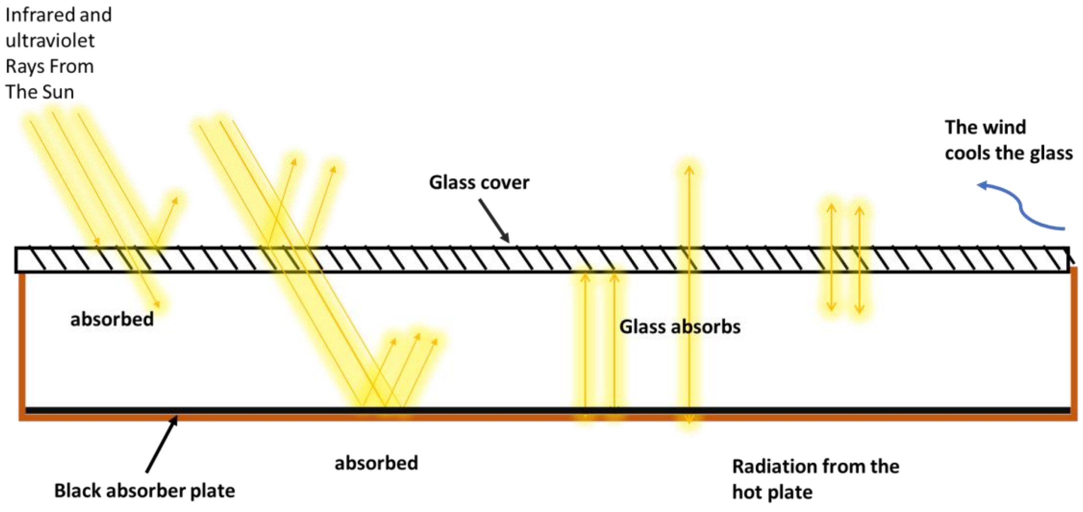
In a collector system, insulation is necessary. The operating principles are identical to those found in liquid complexes. Insulation materials include glass wool, rock wool, and polyurethane foam. Check for leaking to the exterior if glass wool will be used in air collectors. Figure 2.2.



Figuer 2.2: The Insulation in Solar Air Heater system

2.4.3 Transparent Cover In Air Collectors

The collector cover offers solar heat input to the collector and protects the absorption surface from external influences like rain, hail, and dust, in addition to decreasing heat loss to the environment via design. The transparent cover's function is to prevent heat loss to the environment by allowing solar heat in. The covering materials utilized must have a high transmittance rate, with little absorption and reflection. Bulk caps are often composed of transparent materials such as glass or plastic. Glass has the benefit of optical and mechanical qualities that are stable throughout time. (See Figure 2.3) Plastics are more resistant to breakage and more flexible than glass. It is, however, less resistant to scratching and abrasion, and environmental conditions may swiftly alter it. The light transmittance cover is an essential component of the solar collector. It may perform better without the cover when the outdoor temperature is high. When the outside air temperature lowers, the cover material plays an essential role in capturing more heat energy. In two ways, the cover material limits heat loss. First, by delivering visible rays, and second, by reducing wind absorption and the natural load of the absorbent board, the cover material considerably lowers heat loss. It should also be examined for mechanical qualities. It is necessary to assess cold damage and snow load resistance.



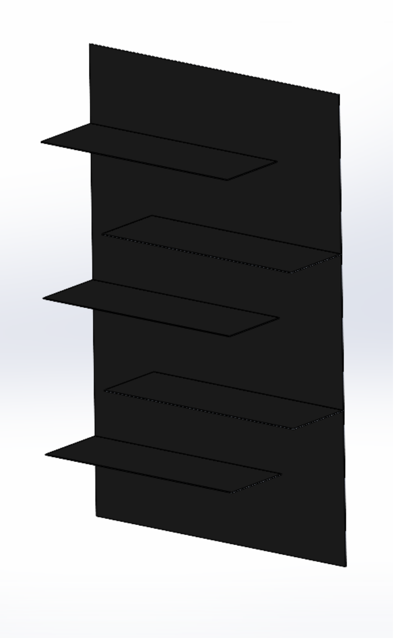
Figuer 2.3: Transparent Cover a Single Glass

2.4.4 Absorber Surface in Solar Air Collector

The absorption surface is the most significant component of air collectors. which captures solar energy and transports it to the carrier medium, where it is converted into useable energy, To a considerable degree, the absorbing surface must transmit the absorbed solar energy to the heat transport fluid. Absorption surfaces with a larger heat capacity respond to the changes in solar energy more slowly. The heat transmission area of the chosen material's volume ratio should be big. When the heat transmission area is big, the absorption surface's volume ratio is also great.

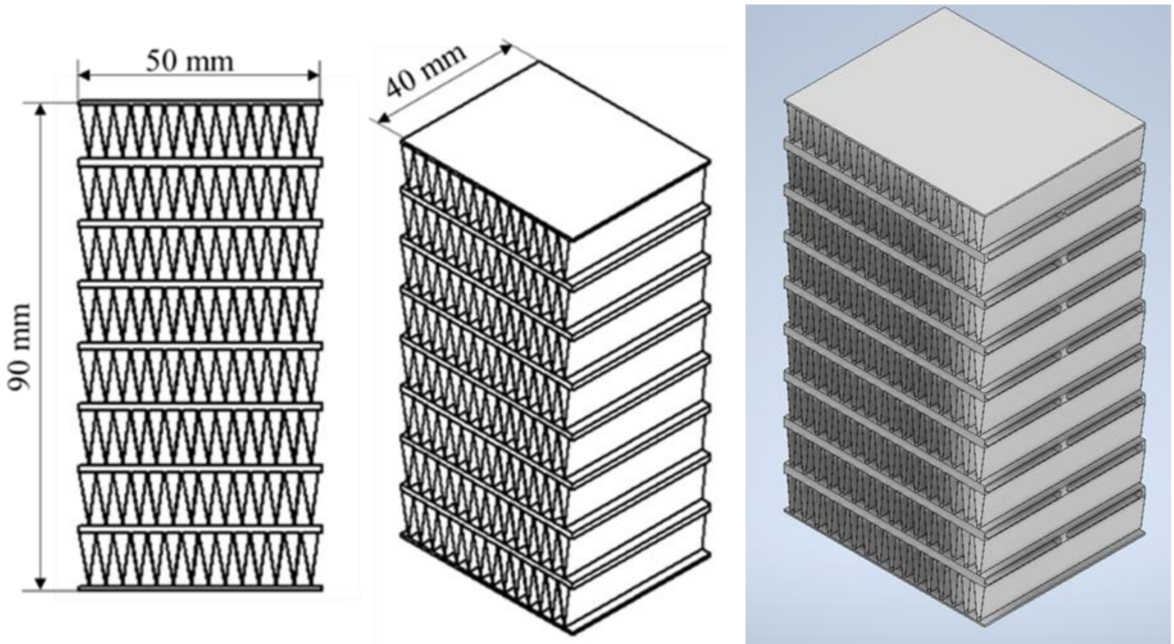
- The heat transmission area on the absorbent surface expands.
- The quantity of energy transmitted to the air rises.
- The absorbent surface absorbs a greater quantity of heat.
- Heat loss is reduced compared to the absorbent surface.

The collector's efficiency is affected by the absorbent surface's coating, shape, and material. The benefit of the coating put to the absorber's surface is that it boosts the solar collector's efficiency (Figure 2.4). The job of the absorbent surface coating is to collect as much solar heat as possible and convert it to heat. As a surface absorbent coating, selective surface coatings and matte black are utilized. The matte black paint absorbs 90% to 98% of sunlight.



Figuer 2.4: Absorber Surface in Solar Air Heater system

Air as a heat transporter has a few benefits over a fluid accumulator, including a simple collector construction. The absorbent plate is unaffected by air corrosion. It is impossible for air to freeze or boil. Air leaks, like water leaks, have no negative consequences. The downside is that air is a poor conductor. like water and other liquids, has a limited capacity to absorb and release heat fast. As a result, fins are added to air intake panels to increase heated surfaces and enhance heat transmission. (See Figure 2.5) Increasing the collector's circulating air flow rate improves heat transmission.



Figuer 2.5: Used Fins in The System

In the air collector, the air should come into contact with superficies as it flows. The heat transmitted to the air body increases as the heat transfer surface increases. Finned panels are hence more efficient. Aluminum is the material of choice in most cases. Also because the metallic substance is an excellent conductor of heat.

Tablo 2.1: Thermal conductivity of some materials

Material	***(W/m K)***
Steel	**0.13**
Aluminum	**0.56**
Copper	**0.96**

The air enters the collector over the absorbent plate. It is give out hot air to outside. Heat loss is decreased since the warmer air does not touch the glass. This system comes at a low cost. The inclusion of fins doubles the surface area of the absorbent plate. On the glass side, heat is lost at the top surface. However, the given out air is will be more than the squandered.

3. MATERIAL AND METHOD

In most cases, flat plate assemblies are made up of a transparent housing, a power generating surface, heat-carrying tubes, an insulating material, and a casing that holds each part in one place. The transparent cover reflects some of the solar energy back into the environment, while the absorber absorbs the rest. The absorbent surface absorbs the majority of the radiation that hits it, with some of it being reflected as long wave radiation towards the transparent cover. Some of the reflected radiations hit the absorbing surface, while others travel through the clear cover and into the environment. The majority of the surface energy of the heated absorbent is transferred to the carrier air. By way of movement and convection, some of the contents of the can are released into the environment.

Solar air collectors are simple devices that heat the air by harnessing the sun's energy. A solar air heater's basic components are an air duct, suction plate, and glass cover. A blower is included in the active solar system. Some changes to the traditional solar air heater were made in this paper. The experimental setup and construction of a solar air collector with fins and the collector surface will be coated with black paint and selective surface paint.

3.1 Measuring Devices Used in the Experiment

3.1.1 Pyranometer

Many measurement equipment such as pyranometer, datalogger, thermocouple, thermal camera, and multimeter were offered to be utilized in experiment applications, and the acquired results were sought to be interpreted in a healthy manner. A pyranometer measuring sensor was used to measure the total quantity of radiation arriving at the unit surface horizontally.

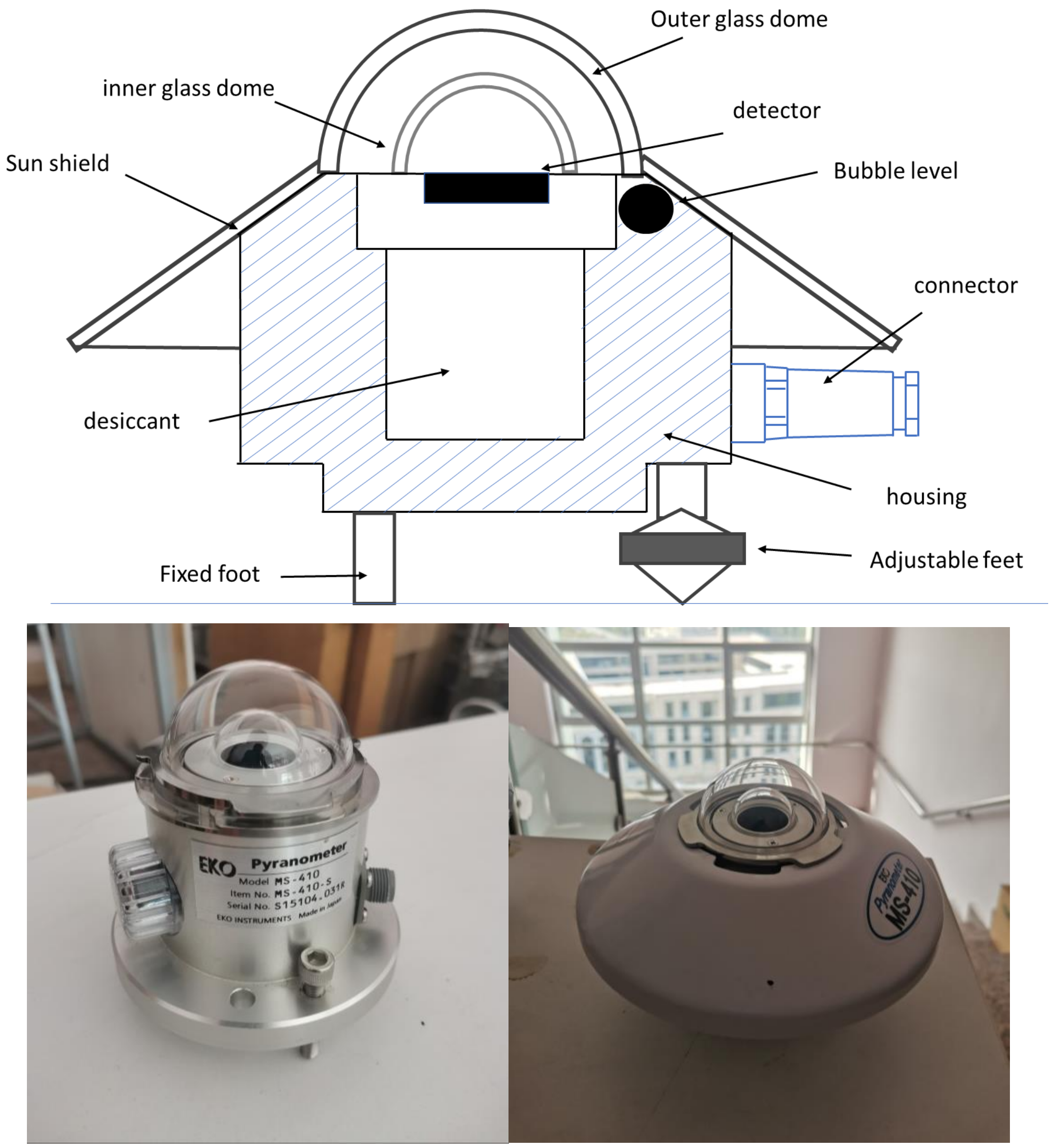


Figure 3.1: MS-410 First class pyranometer

The figure shows 3.1 MS-410 Class I temperature metering sensor. To measure the quantity of radiation, the thermometer should be set parallel to the surface. The thermometer is composed of black metal that incorporates a sort of temperature sensor, a blend of copper and copper-nickel, which is put behind a two-layer hemispherical glass. In order for the gadget to detect the quantity of global radiation, first of all, electrical motion is produced by absorbing sunlight arriving on the surface of the black metal. When this electromotive force is compounded in a given length of time, we arrive at the quantity of global radiation.

3.1.2 Datalogger

A datalogger, which we may describe succinctly as a data logger, monitors and records data such as temperature, pressure, humidity, and vibration throughout a particular period of time owing to the electrical impulses collected from the sensors. The GRAPHTEC GL240 10-channel data recorder was utilized in experimental applications.

Figure 3.2: Graphtec gl240 datalogger

Figure 3.2 depicts the GRAPHTEC GL240 10-channel datalogger in experiment applications. Thermocouples, which measure temperature, and pyranometers, which measure the amount of global radiation, were connected to the datalogger, and the measured data were recorded over the time interval specified. The measurement data collected during the experiment is transferred to a portable computer for analysis.

3.1.3 Thermal Camera

Figure 3.3: Testo 875-2 thermal camera.

The thermal camera used in the experiment is shown in the figure 3.3. Thermal cameras detect unseen infrared thermal energy and present it on the screen as a picture. The temperature values on the photovoltaic cells were obtained in the experimental application by imaging with the Testo 875-2 thermal camera. These captured photos are saved to a computer and evaluated. It is feasible to evaluate the results of the analyses by looking at the average and maximum temperature distributions created on the PV cell over the chosen time frame.

3.1.4 Thermocouple

Figure 3.4 depicts the manifolds and thermocouples utilized in experiment applications. It is a temperature sensor made of two distinct conducting materials, also known as a thermocouple. When the exposed ends of these distinct conductive materials are joined and heated, voltage is generated. The two locations that are heated by connecting are referred to as hot spots, while the two areas that are exposed are referred to as cold spots. The resultant voltage value varies based on the kind of thermocouple used and the temperature of the two connected ends. Because of their cheap cost and endurance, thermocouples are often utilized. Thermocouples were widely employed in the experimental application by connecting to a datalogger.

Figure 3.4: Thermocouple.

Which is used as a data logger. The thermocouples used to measure inlet and outlet.temperatures are positioned at the midpoint of the flow section. Nickel-chromium-nickel (NiCr-Ni) type K thermocouples with a thickness of 0.5 mm were used for all temperature measurements. The measurement accuracy is 0.01°C and the measurement range is -200-1200°C.

3.1.5 Anemometer

An anemometer from (Figure 3.5) was used to measure air flow velocity and temperature in an air heater. Thermal anemometer can be used to measure very low air velocity. The anemometer used has a measurement accuracy of 0.1 m/s and can measure between 0.1 and 25 m/s. Air temperature range from 0°C to 50°C while measuring air velocity. The combination of hot wire and standard thermistor provides fast and accurate measurements that records maximum/minimum readings with retrieval and data retention. , the vane anemometer probe was operated with the center of the measured tube and kept perpendicular to the flow. The fluid velocity is adjusted with the help of a lapel placed in the inlet of the air heater.Microprocessor circuits provide the maximum possible accuracy, provide special functions and features. Large, illuminated LCD display reads air speed and temperature The portable anemometer provides fast and accurate readings with a multifunctional digital readout for measuring air flow: m/s, km/ºC/F.

Figure 3.5: CEM DT8880 Anemometer.

3.2 Solar radiation

Using a pyranometer, the total sun irradiation was calculated. Direct, Hb, and diffuse solar radiation (Hd) on a horizontal surface are all included in the global radiation. As mentioned in the Equation

$$H = H_b + H_d = I_b \sin\alpha_s + H_d \quad (1)$$

Where Ib and α_s stand for the sun's direct rays and its altitude, respectively. The calculation of the solar height is (Duffie et al., 1980)

$$\sin\alpha_s = \sin\delta\sin\phi + \cos\delta\cos\phi\cos\omega \quad (2)$$

Where ϕ the location's latitude, ω the sun's hour angle, and the declination angle are given. The direct and diffuse radiations may be identified using the clearness index K_T. The ratio of the extraterrestrial radiation on the horizontal surface to the global solar radiation is used to define it.

$$K_T = \frac{H}{H_0} \quad (3)$$

Boes et al. (Boes et al., 1976) established an equation regarding to the clearness index for the range of $0.85 > K_T \geq 0.3$. The direct solar radiation is decided by

$$I_b = -520 + 1800K_T \quad (1)$$

Incident solar radiation on an inclined surface can be determined by (Duffie & Beckman, 2013)

$$q_s = I_b \cos\theta + H_d \cos^2\frac{\beta}{2} + H\rho_r \sin^2\frac{\beta}{2} \quad (2)$$

where θ is the solar radiation's incidence angle effective diffuse ground reflectance of incoming solar energy on a horizontal surface. ρ_r is described by the symbol β. The SAH's angle of inclination is. The angle of the sun's incidence is governed by

$$\cos\theta = \sin\delta \sin(\phi - \beta) + \cos\delta \cos(\phi - \beta)\cos\omega \tag{3}$$

3.3 Thermal performance Analysis

3.3.1 First Law Analysis of Thermodynamics

The parameters of the absorption surface utilized in the air heater, solar radiation intensity & angle of incidence, and mass flux all affect the first law of thermo-dynamics (energy) efficiency for solar air heaters. The first law of thermodynamics is used to analyze energy in air heaters. The ratio of useable heat transferred by the intensity of solar radiation falling on the heater's absorption surface area to the air is described as the instantaneous energy efficiency of air heaters. (Tyagi et al., 2010).

$$\eta_{th} = \frac{\dot{Q}_u}{q_s A_{SAH}} \tag{7}$$

The useful heat is calculated using this Equation

$$\dot{Q}_c = \dot{m} c_p . (t_{out} - t_{in}) \tag{8}$$

The flow rate of the working fluid;flow rate of the working fluid;

$$m{=}\rho.UASAH \tag{9}$$

The area of the section where the flow takes is calculated as follows this Equation;

$$A_{SAH} = \frac{\pi D^2}{4} \tag{10}$$

The final energy efficiency of solar air heater can be expressed as follows this Equation;

$$\eta_{th} = \frac{\dot{m}. C_p (T_{out} - T_{in})}{q_s . A_{SAH}} \tag{11}$$

3.3.2 Second Law Analysis of Thermodynamics

Exergy analysis is a method for getting energy and preserving mass in a system by employing the second law of thermodynamics to build and enhance energy and also other systems. Exergy analysis and system losses can be performed to enhance the performance level. The second law of thermo-dynamics tells us how much energy is accessible to heat-generating equipment like air heaters. Exergy is the term for this useful energy. Exergy is a metric for determining the type and quality of energy required. The system's energy is split into two categories: exergy & energy. The quantity of usable working opportunities in a liquid or mass as a result of the liquid or mass's non-equilibrium state with regard to changing in reference circumstances is referred to as exergy (I. Dincer, 2002)

For a steady-state scenario, the exergy balance equation is as follows:

$$\sum \dot{E}x_{in} - \sum \dot{E}x_{out} = \Delta \dot{E}x_{dest} \tag{12}$$

The exergy balance equation is as follows:

$$\sum \left(1 - \frac{T_{amb}}{T_s}\right) \eta_{opt} \dot{Q}_S - \dot{W} + \sum \dot{m}_{in}\, \psi_{in} - \sum \dot{m}_{out}\, \psi_{out} = \dot{E}x_{dest} \tag{13}$$

When the entrance and output of energy are stated as

$$\psi_{in} = (h_{in} - h_{amb}) - T_{amb}(s_{in} - s_{amb}) \tag{14}$$

$$\psi_{out} = (h_{out} - h_{amb}) - T_{amb}(s_{out} - s_{amb}) \tag{15}$$

The following equation is obtained in the solar air heater by inserting the aforementioned equations in the exergy balance.

$$\sum \left(1 - \frac{T_{amb}}{T_s}\right) \eta_{opt} q_s A_c + \dot{m}[(h_{out} - h_{in}) - T_{amb}(s_{out} - s_{in})] = \dot{E}x_{dest} \tag{16}$$

The solar energy absorbed by the air heater absorber surface is expressed by the following equation

$$\Delta h = h_{out} - h_{in} = c_p(T_{out} - T_{in}) \tag{17}$$

$$\Delta s = s_{out} - s_{in} = c_p \left(ln \frac{T_{out}}{T_{in}} - R\, ln \frac{P_{out}}{P_{in}} \right) \tag{18}$$

The entropy production exergy destruction is computed as

$$\dot{E}x_{dest} = T_{amb}S_{gen} \quad (18)$$

The solar air heater's exergy efficiency may be determined using the following formula:

$$\eta_{ex} = \frac{\dot{m}_a c_{p,a}(T_{out} - T_{in})}{\left[1 - (\frac{T_{amb}}{T_s})\right]\eta_{opt} q_s A_{SAH}} = \frac{\dot{m}_a(h_{out} - h_{in})}{\left[1 - (\frac{T_{amb}}{T_s})\right]\eta_{opt}\dot{Q}_s} = 1 - \frac{T_{amb}S_{gen}}{\left[1 - (\frac{T_{amb}}{T_s})\right]\eta_{opt}\dot{Q}_s} \quad (20)$$

The following equation yields the Nusselt number:

$$Nu = \frac{hL_c}{k} = 0.56(Gr\, Prcos\,\beta)^{1/4} \quad (21)$$

D_h is the equivalent hydraulic diameter, which can be found by

$$D_h = \frac{2WL}{W + L} \quad (22)$$

The Reynolds number of air flow through the SAH is decided by

$$Re = \frac{VD_h}{\nu} = \frac{\rho V D_h}{\mu} = \frac{\dot{m}D_h}{\mu A_{ch}} \quad (23)$$

3.4 Experimental Setup

Experimental research has been done to determine the thermal performance of a proposed solar air heater (SAH) with rooftop radiator fins and to compare it to a flat panel system. SAHs and measuring instruments are the two fundamental components of the experimental setup. The inside measurements of SAHs are 600 x 400 x 100 mm. The diffusing air channel is 100 x 100 mm in size. Helix fans were used to circulate the air. The aluminum absorbent plate has measurements of 600x400x1. To maximize absorption, the absorbent plates and the tops of the radiators are painted black. An EKO MS-410 Pyranometer was used to measure the total amount of sun radiation. The entrance, outflow, surface, and ambient temperatures were measured using K-type thermocouples. a potentiometer, which is used to split voltage or restrict current in circuits, was utilized to alter the inlet air's velocity. An anemometer with temperature sensitivity was used to assess air velocity. West of the Black Sea (41.6°N, 32.3°E), the Bartin University office building's roof is where the experiment was carried out. SAHs were pointed at a 30degree slant southward. The experiment was carried out on 10.05.2022, a clear day. Figure 3.6 displays the experimental set-up and the locations of the thermocouples.

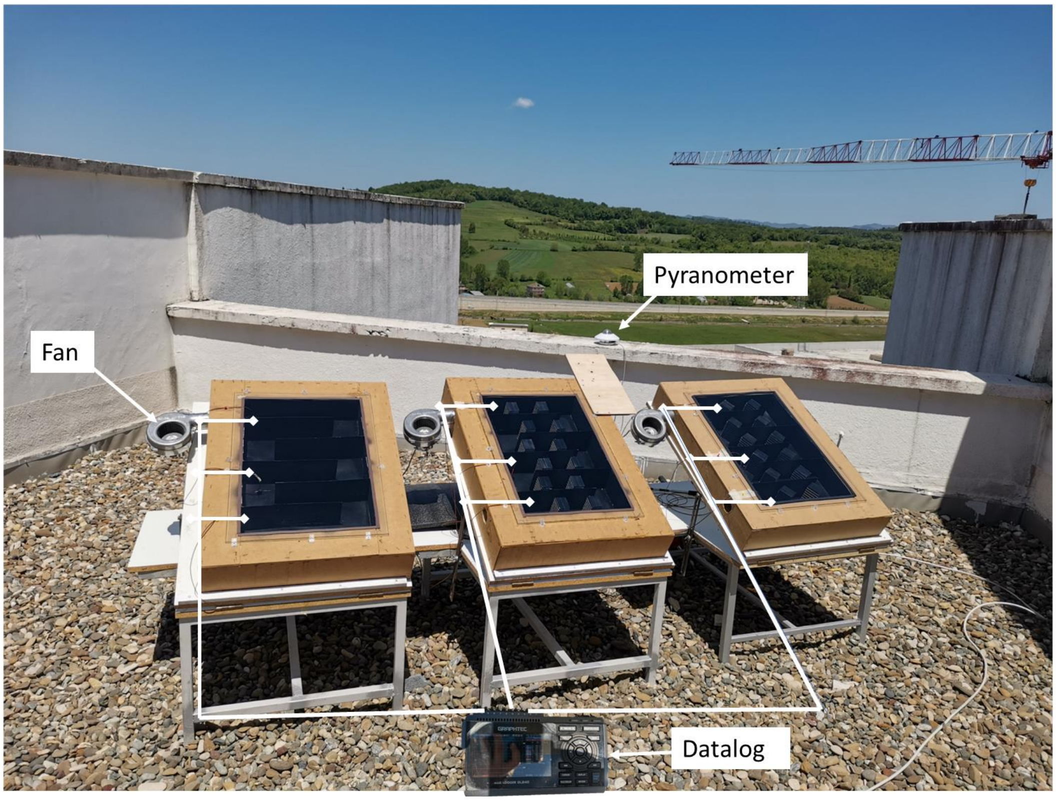
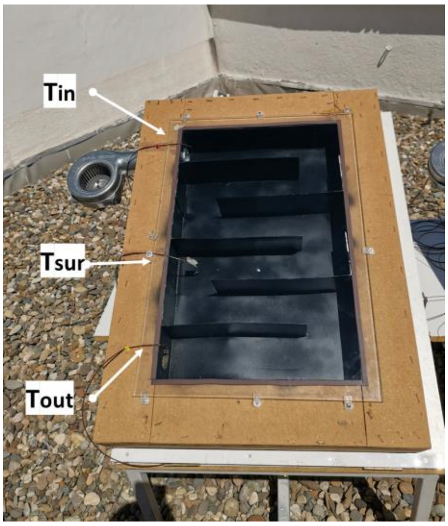
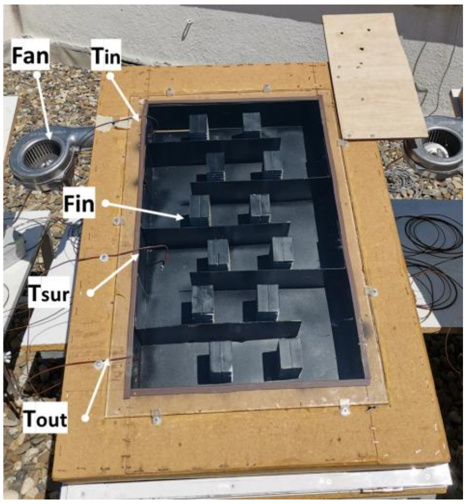


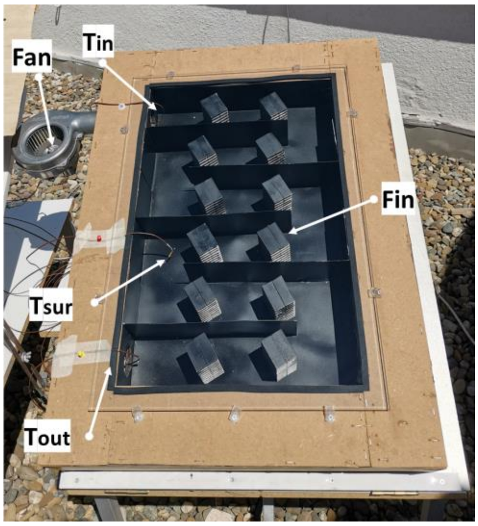
Figure 3.6: Experimental setup of solar a solar air heater having enhanced heat transfer surface area with plate-fin geometry.



(a)



(b)



(c)

Figure 3.7: Solar Air heater types a) Flat b) Fin c) Angle fin.

4. RESULTS AND DISCUSSION

The major goal of this experimental study is to use a passive technique to boost the traditional solar air heat's efficiency of heat transmission. Using plate-fin geometry, a new absorber plate with increased heat transfer surface area was created. By contrasting the suggested system with a traditional solar air heater, the thermal performance of the proposed system was experimentally examined. The tilt angle and direction of the proposed and conventional systems were identical. The tests were carried out on a day with a clear sky.

(Figure 4.1) shows the global, direct and diffuse solar radiation. The experiment was conducted on a clear sky day . throughout the day is depicted as a result of the trials with the newly created solar air heater. The radiation intensity starts at 700 W/m2 at 9:40 and reaches its peak at 13:00, according to an examination of the graph. While it reaches a high of 1180 W/m2, it drops to a minimum of 500 W/m2 around 17:00, just before sunset. The intensity of solar radiation took identical levels for all different types of air heaters.

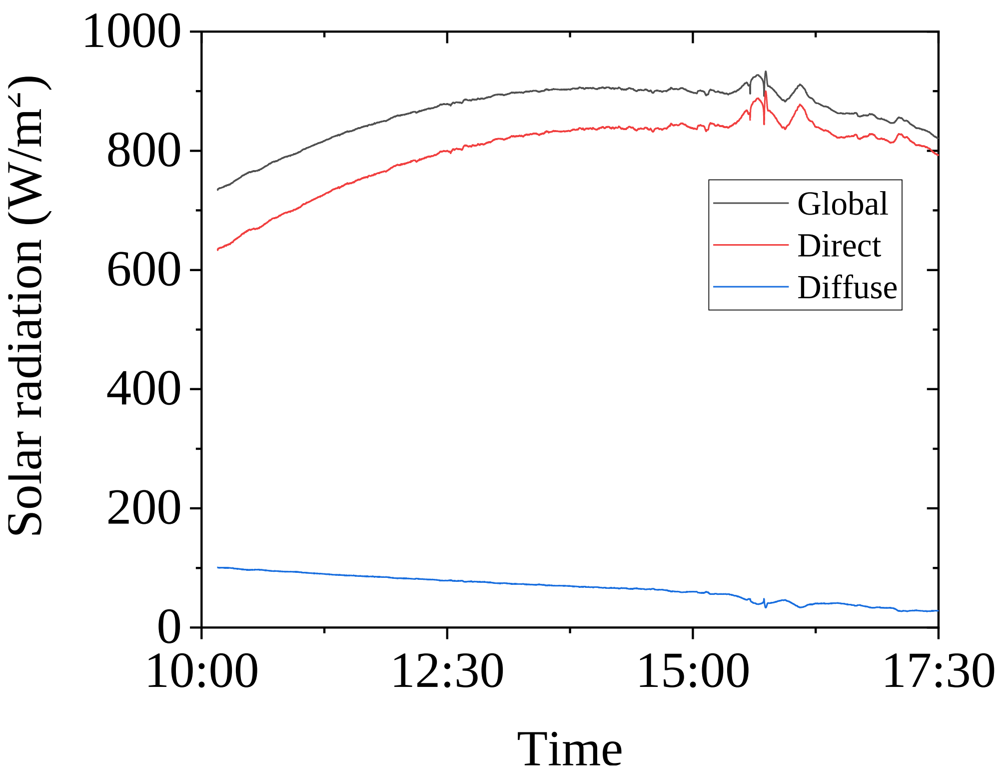


Figure 4.1: Global, direct and diffuse solar radiation on a clear sky day.

The (Figure 4.2) displays the air input, air output, and air outflow measurements for each of the three cases. It displays the daytime time-dependent difference between input and output temperatures. The temperatures of the inlet air were virtually comparable. Throughout the trial, the input temperature ranged between 17 and 22 °C. It also shows the temperature outside. The suggested SAH offers a greater temperature for the air exit temperature. The type I air heater produces temperature changes throughout the day that range from 5.2 to 23.3 °C. And the second type is 6.4 °C to 20.9 °C throughout the day. The third type form is throughout the day 8 °C to 27.6 °C.

(Figure 4.3) shows the temperature differences between entry and exit temperatures. The proposed system successfully achieved a temperature difference of 23.3 °C between air entering and leaving the system. The largest increase in temperature is observed to occur around midday (13:00), when the intensity of solar radiation reaches its peak levels and the SAH reference system is at a temperature of about 44.5 °C. During these hours of maximum solar radiation, it reached a higher differential temperature of about 4.5 °C. By midday, the mean difference in the proposed system was about 4° higher at 44.5 °C in a fin type III air heater. The lowest temperature difference was obtained in a type I air heater at 22.7 °C, and by 12:30, the largest temperature difference between the two cases was 4 °C, and the variations began to decrease in the afternoon solar.

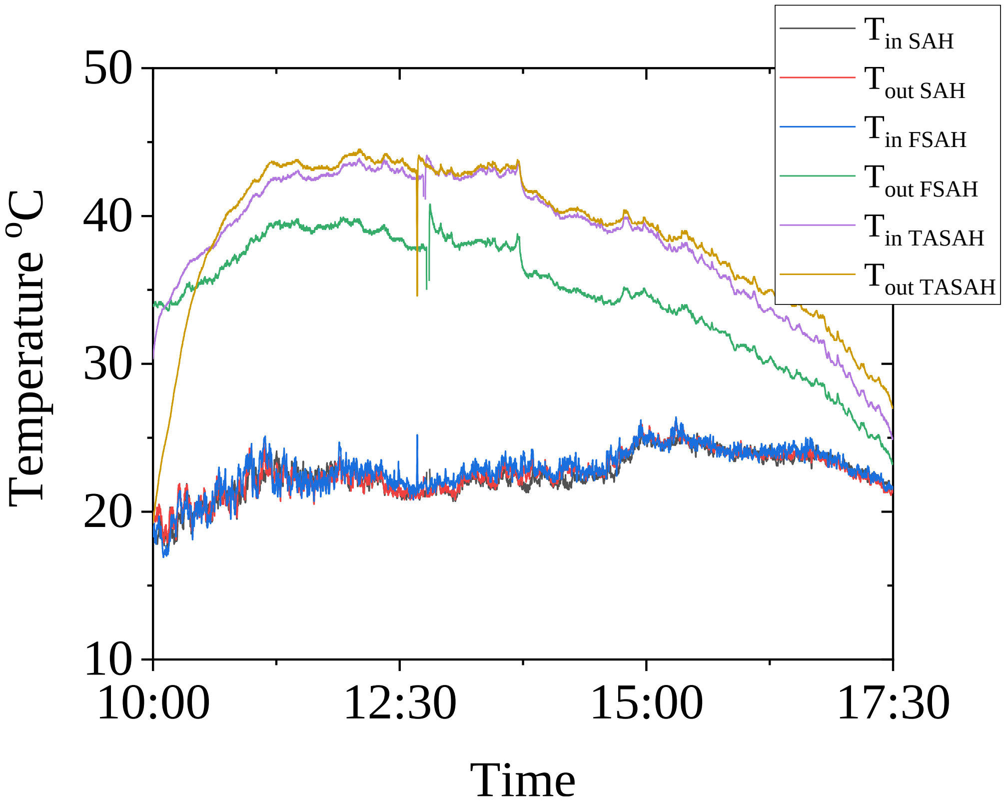


Figure 4.2: Air inlet, and air outlet temperature of a flat SAH and SAH having fin.

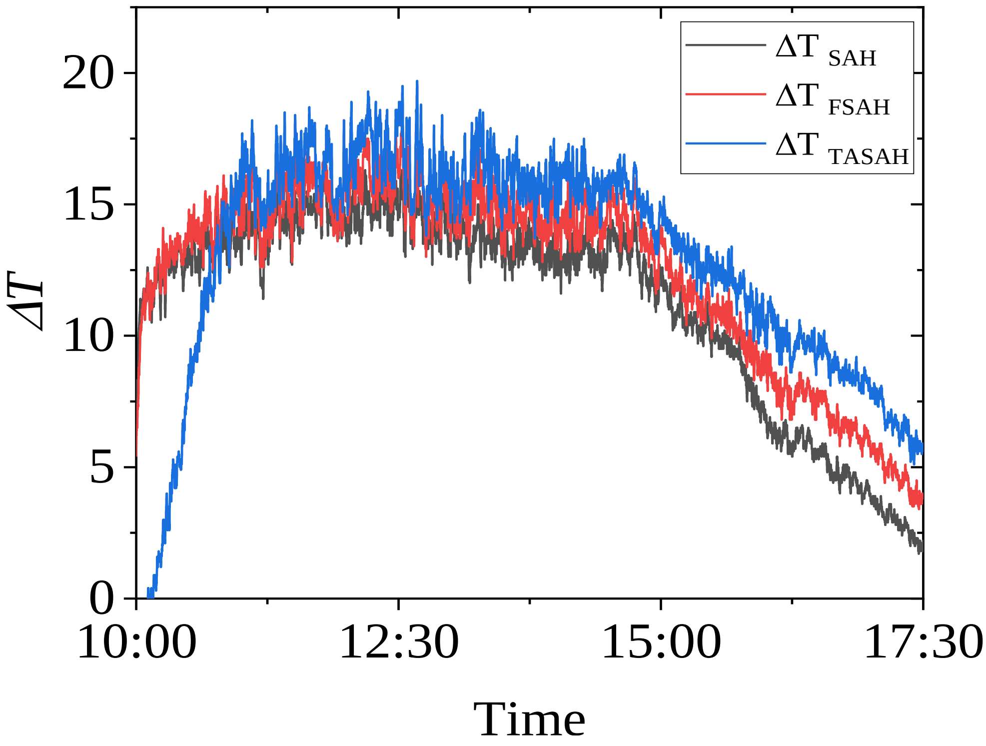


Figure 4.3: Temperature difference between outlet and inlet.

The (Figure shows 4.4) the energy efficiency of the proposed and conventional SAHs. The efficiency of the proposed system is the efficiency of the reference system before noon and after solar noon hours, achieving a performance about 10% higher than the reference system. The differences between the two cases gradually decreased with the increase in their thermal efficiency. The average thermal efficiency of FSAH was about 66.20% while the proposed system achieved the highest efficiency of about 75.20% during the experiment. The exergy efficiency of both SAH and SAH that increase heat transfer surface area by employing plate fin shape is shown in the (Figure 4.5) In both situations, the energy efficiency were substantially much lower the thermal performance. The reference system's average efficiency was around 24.20%, whereas the suggested system's average efficiency was about 29.40%. The suggested system had an average external energy efficiency that was approximately 5.2 %greater.

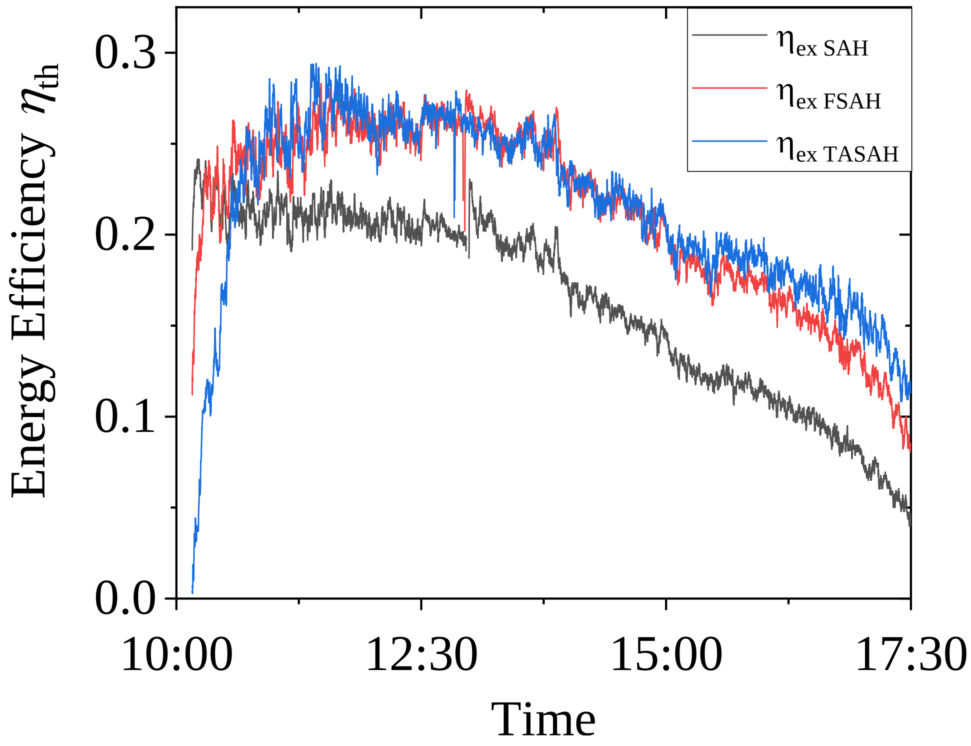


Figure 4.4: Energy efficiency of a flat SAH and SAH having fin.

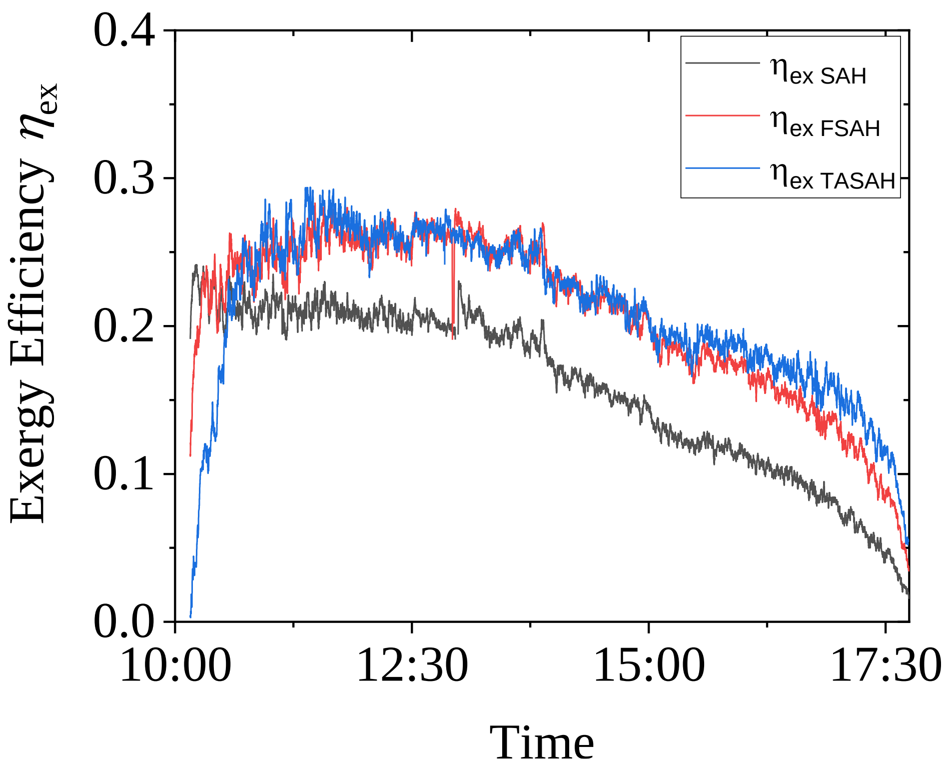


Figure 4.5: Exergy efficiency of a flat SAH and SAH having fin.

The (Figure 4.6) shows the highest value of friction factor is 0.76 for a type III air heater with 30° fins. The highest friction factor for type I is 0.58, the lowest friction factor occurred with 0.0064 and 0.0418, respectively, are at the top of the Reynolds number. The values of the friction factor decrease depending on the increase in the Reynolds number. If an evaluation of the highest Reynolds number is made, it is found that the friction factors are 0.0418 for the first type, 0.107 for the second type, and 0.077 for the third type, as can be understood from here, the values of the friction factor increase with Addition of fins, while the values of friction factor decrease with the change of angle for type III. The fluid hits the fins in the air heater and thus the fluid's friction factor values increase. The value of the friction factor decreases as the Reynolds number increases and the angle changes. In this study, The Reynolds number values as in (Fig 4.7) were obtained using Equation 3.23 as a result of measurements made with different fluid flow rates between 26000 and 28500. The flow characteristic is determined by the Reynolds number. A difference in Reynolds number for a fluid flowing through a channel indicates a turbulent and continuous flow. The comparison was made between the previous form of the coefficient of friction and it was noted that the relationship between the drop in pressure, the flow velocity and the Reynolds number is a positive one. When the Reynolds number or the flow velocity is increased, the friction coefficient decreases.

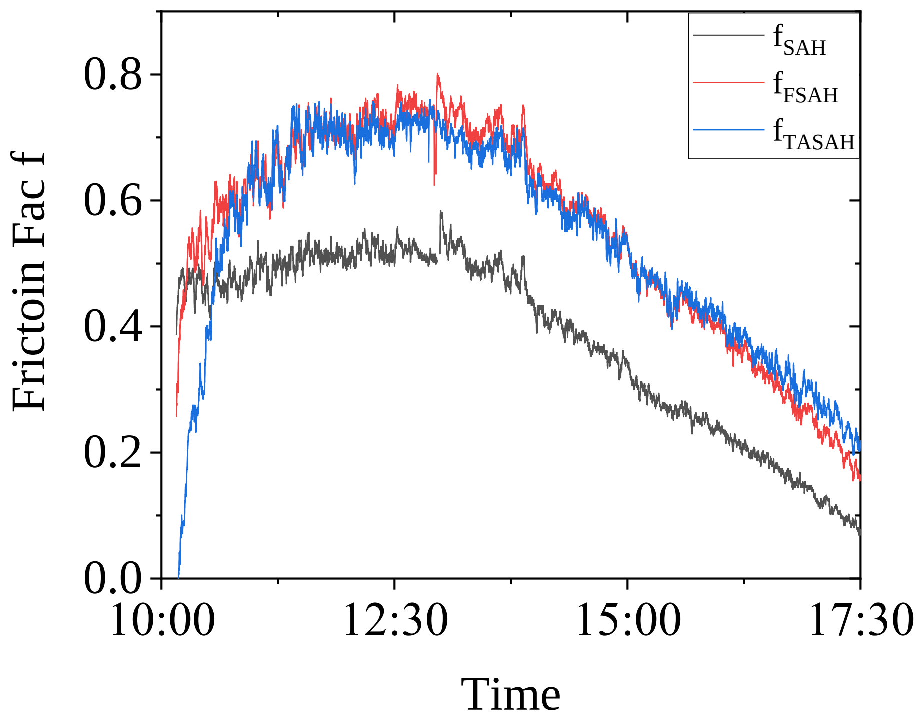


Figure 4.6: Friction factor of a flat SAH and SAH having fin.

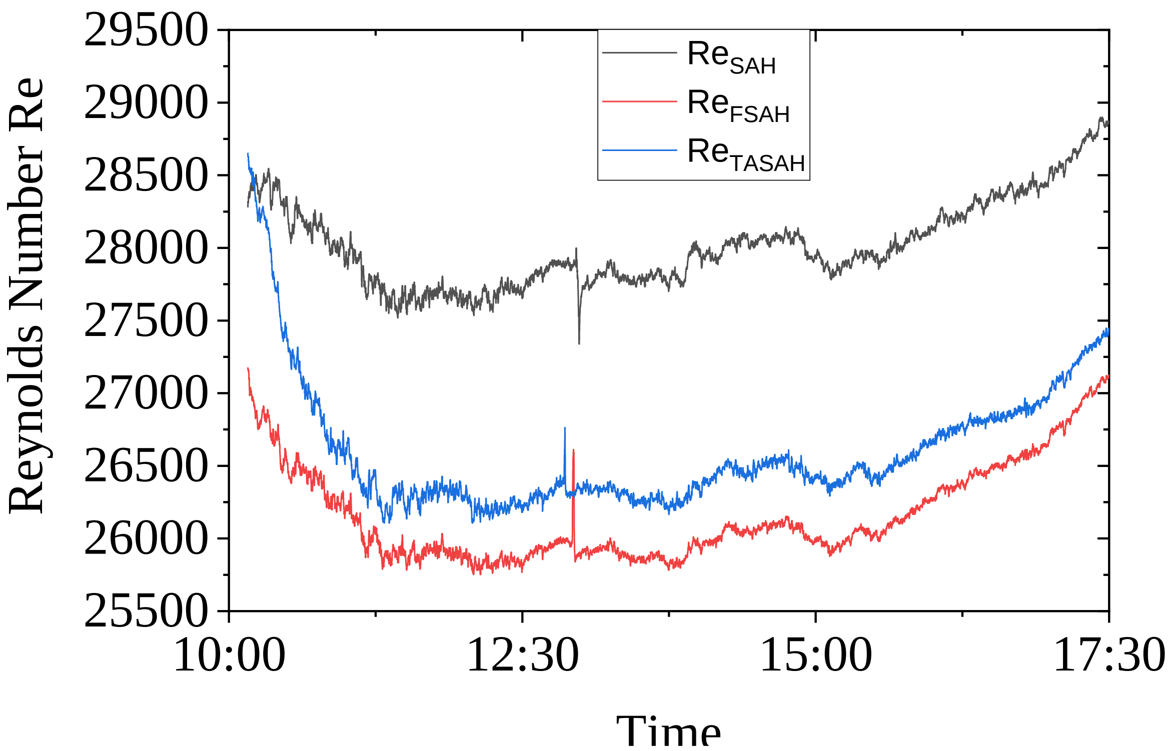


Figure 4.7: Reynolds Number of a flat SAH and SAH having fin.

The (Figure shows 4.8) the ratios of the Nusselt number values obtained from the air heater. Depending on the increase in the Reynolds number, the values of the Nusselt number increase, while the values of the friction factor decrease. As can be seen from the figure although the Nusselt values obtained from the Type I (SAH) air heater are higher than the rest, it is clear from the figure that the Type II (FSAH) fins produce the least number and Type III (TASAH) the 30 degree installed fins have the highest number from Nusselt. Type II Fins have fewer Nusselt because of the holes and because some flow circulates through the holes and the air velocity decreases as the area increases. The fins installed at an angle of 30 degrees (Type III) are responsible for the sharp drop in fluid velocity. Hence, the fins (Type II) show a lower value of the Nusselt number which indicates a lower rate of convective heat transfer. As it can be understood from here, distance and angle have an effect on increasing the amount of heat transfer, and thus increase heat transfer from the absorbing surface to the liquid.

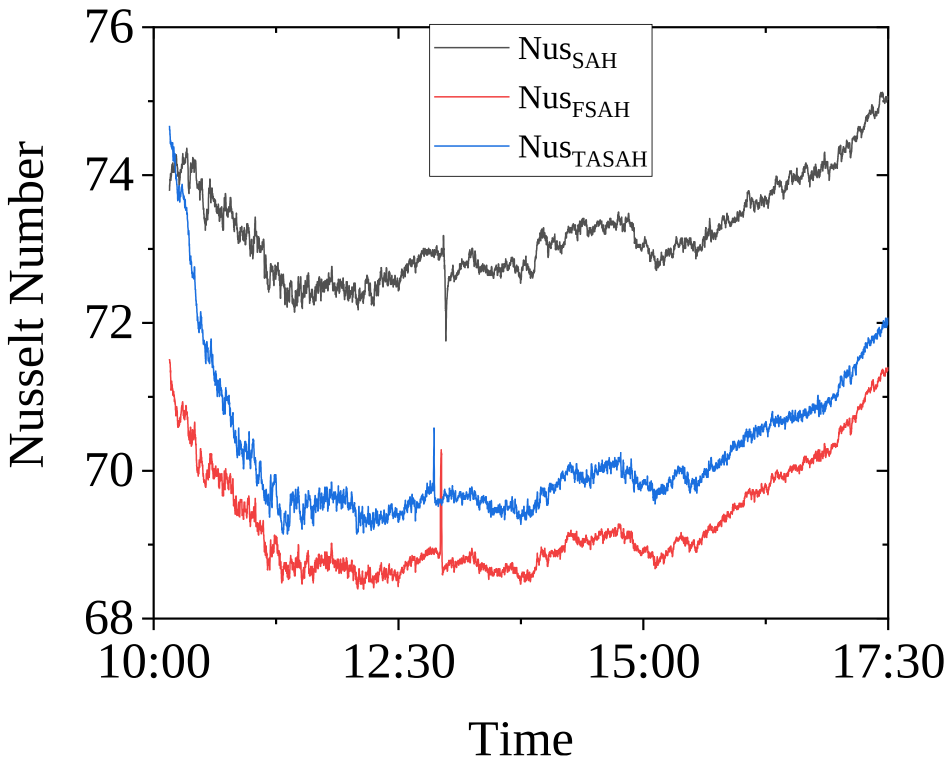


Figure 4.8: Nusselt Number of a flat SAH and SAH having fin.

As shown in the (Figure 4.9) shows a block flow diagram. It is observed that after 13:00 the pressure drop increases with the increase in the mass flow rate. It is clear that the mass flow drop of the second type is much higher than that of the third type due to the increased friction when using a finned plate. In the third type, fins at an angle of 30 degrees were used, the mass flow would be higher than the second type. The highest mass flow rate ratio was 0.0128 and 0.0115, respectively.

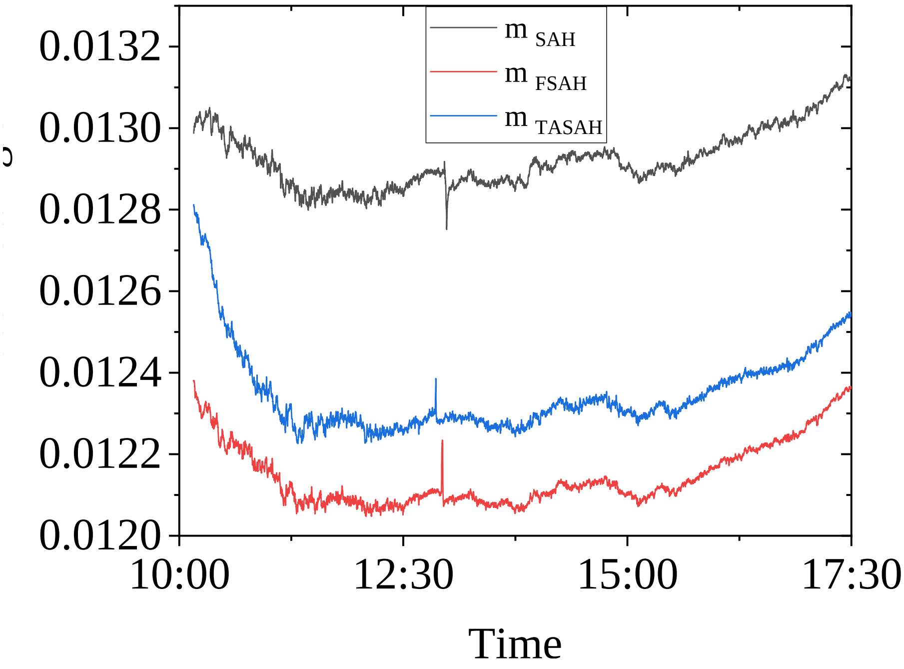


Figure 4.9: Mass Flow of a flat SAH and SAH having fin.

As shown in the (Figure 4.10) when the pressure is higher, the mass flow is less. The decrease in the flow rate increases with the increase in pressure. An increase in the flow rate leads to a decrease in pressure when the pressure drop decreases due to a decrease in the friction factor f (i.e. the friction coefficient decreases with the increase in the Nusselt and Reynolds number). Also, the pressure drop in the flat type is higher than in the finned type due to the mixing of the flow and the formation of a secondary flow in the channel. Finally, the flat SAH has a greater pressure drop than that of the SAH with fins.

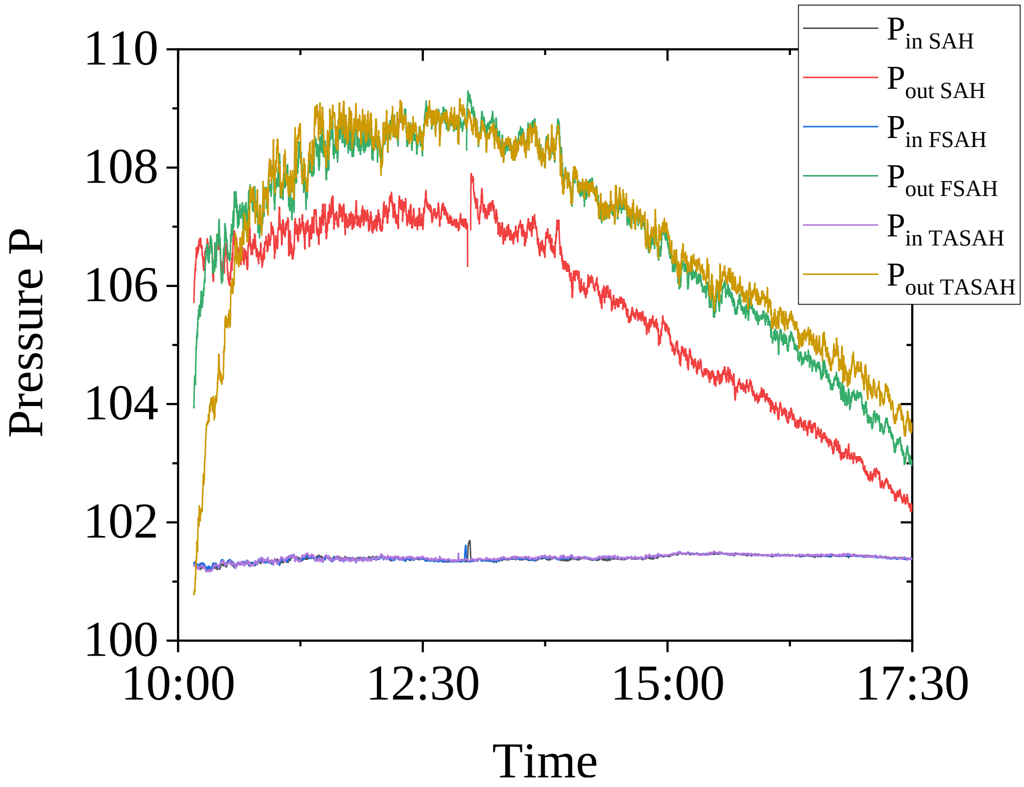


Figure 4.10: Pressure of a flat SAH and SAH having fin.

5. CONCLUSION AND RECOMMENDATIONS

Heat exchangers are widely used in many aspects of modern life. One form of heat exchanger that converts solar energy into air is called a solar air heater. In this study, the methods used to improve the performance values of the heat exchanger, the experimental results of the new straight air heater (flat type) and air heaters with different types of fins (0° angle fins and 30° angle angles) are discussed. The use of fins in an air heater aims to significantly improve the performance of an air heater. For the purpose of blocking the different air flows used in the system, the researchers investigated energy values, energy efficiency and thermal optimization, Reynolds numbers, friction factors, different suction element designs, and different air flow rates. This study, unlike other studies, aims to increase efficiency and reduce heat loss using modifications that have not been done before because what is usual with collectors is lower efficiency and heat loss from glass, and it is noted how the values of solar radiation and weather conditions in the experimental environment and experimental site affect them. In flat panel solar collectors, it continues to operate at medium efficiency by transmitting solar radiation directly to the absorbers and giving it to the system, and on the other hand, the finned solar collector is transmitted to the heat absorber, by additional heating air from the fins. In this direction, it can increase the thermal efficiency. The tests in this study were carried out using different flow rates of mass and density of the liquid. The results obtained from this study can be summarized as follows;

- The developed model offers the plate and fin solar heater good performance results. Testing has been done on the various solar air heater performance facets. The efficiency of the collector is increased by increasing the air flow rate via the solar air heater.
- Using fins to raise the thermal performance of solar air heaters is advised because they increase the surface area of heat transfer and the heat transfer coefficient. Finned solar air heaters have been shown to provide better temperatures and thermal efficiency than flat collectors when the same operating circumstances are used.
- The difference in inlet and outlet temperature caused by air heaters takes its highest value at noon when the intensity of solar radiation is maximum. When we evaluated it according to the time of noon, an increase in the efficiency of type I flat air heaters was found to be 36.08%. In a type II air heater with fins at an angle of 0°. An increase in efficiency of 40% was obtained. In a type III heater with fins at an angle of 30°, an efficiency increase of 44% was obtained.

- The highest temperature difference was found for the first flat type 7 °C, in the second type air heater (0° fins) 12 °C and in the third type (30° fins) 15 °C. The experiment was carried out at different times of the year (September, May) in the same climatic conditions. Similar degree difference was obtained.
- For Type III air heater, which has the highest energy efficiency, by changing the fin angle from 0° to 30°, the energy efficiency increased by 10% compared to the first type, the efficiency of the air heater increased as the air touched more surfaces
- The values of the friction coefficient were compared with each other obtained from an air heater (Type I, Type II, and Type III). When examining the experimental results obtained as shown in the Fig (4.7). and the type III was to obtain the best coefficient of friction.
- The decrease in temperature differences was quantified by increasing the fluid flow rate. Depending on the increase in fluid flow, the difference in outlet temperatures of the air heater also decreases.
- Depending on the increase in the Reynolds number, the values of the Nusselt number increase, while the values of the friction factor decrease. Since the highest value of the friction factor is 0.76 for a type III air heater with 30° fins. if the lowest value was obtained from the Re number and Nu number.
- According to the energy and exergy efficiency analysis carried out, at 12:00-13:00, the highest energy and energy efficiency of all types of air heaters was observed , especially the third type was the highest . 74.85% and 29.4%, respectively,
- The experiment was carried out at two different times of the year and the values obtained as a result of the equations (energy equations, energy efficiency, Nusselt number, friction coefficient and heat ratio values depending on the Re number) were compared and found to be in agreement with a margin of error of ±10%.

In order to use energy effectively, the design of systems that contribute to thermal recovery is becoming increasingly important. The efficiency of small, low-cost systems can be increased to the energy efficiency obtained from larger systems with sophisticated designs. Thanks to the fins used in this study, although higher friction factor values were obtained compared to the flat type air heater, it was observed that the values of the friction coefficient remained small besides the thermal improvement and efficiency of the air heater.As a result, it was determined that this experimental system could achieve above-average efficiency compared to similar studies. In addition, a cheaper system is obtained using aluminum fins, which are used as an absorbent element. In this study, the system can be developed by changing the material or gas angle of the fin and perform analyzes using other waste heat to make it better and more useful. As a result, progress will be made to further reduce heat loss in business continuity, further increase efficiency and reduce installation costs.

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