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A Comprehensive Study on the Development and Applications of Single-Pass Solar Air Heaters

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Abstract: *SAH collector are used to capture warmth from solar radiation, give it to the operating fluid and that warm fluid may be used in various packages. In this study evaluation of the thermal. Performance of single pass solar air heater collector with ribs and without ribs absorber plates for different literature review has been conducted. Renewable energy is the most important form of energy that is produced from the use of resources available in abundant quantities in daily life, such as wind, solar energy, and water movement during tides, rain and other available and usable sources. Solar collector one kind of exchanger that given internal energy from solar energy, and the type of the solar collector that utilized in numerous cutting edge applications is solar air heater, such as engineering application, for heating purposes, in drying (drying agricultural crops, fruits and vegetables) and other application. Solar collectors used the direct sun to conduct tests, this means having many weather limitations, high wind, climate difference and other obstacles facing the research. Different cooling methods have been developed over the previous years to ensure that many thermal applications maintain a level consists of maximum internal heat transfer. The enhancement of heat transfer is very effective and important field of engineering research since it helps to increase the effectiveness of the system. Appropriate heat transfer techniques may realize considerable technical advantages and savings of costs. The show article points to display a comprehensive literature Review the history, basics and most recent detailed advancements within the field of convective sun based discuss heating systems. Different plans of sun based collectors, such as emptied tube, level plate, multi-lane, cross-section of the stream path, etc. are detailed and discussed.*

Keywords: *solar energy, single-pass solar air heaters*

1. Introduction

Sun-powered test system is a gadget used to mimic the sun by utilizing various lights and photovoltaic cells and gives lighting like daylight. The motivation behind the sun based test system is to give research centre conditions to the experience of sun-powered cell, sunscreens, plastics and different materials. The sun oriented test system is a gadget whose light source can offer comparable power and unearthly synthesis to the nature daylight. It is broadly utilized as a controllable indoor test office offering lab conditions for sunlight based cells, sunscreens, plastics, and different materials and gadgets, which are delicate to daylight. A sunlight-based test system generally comprises of three significant parts: (1) light sources and related force supply; (2) any optics and channels used to alter the yield bar to meet the prerequisites; (3) essential controls to work the test system (Sodha & Bansal, 1987). Xenon lights or other fake light sources are generally picked as the light wellspring of a standard sun-oriented test system. In any case, there are contrasts between counterfeit light sources and nature daylight, both in power and unearthly structure, which just with the assistance of optics and channels can be adjusted to meet the nature daylight.

Besides, as the open-air condition is time subordinate, it is important to characterize a standard test condition for the sunlight based test system. To rise a bunch of standard test conditions for the earthbound application PV cell, two workshops, supported by ERDA and NASA, occurred in 1975 and 1977, and a last report of standard earthly photovoltaic estimation strategies, including nitty gritty portrayals of standard sun-based test systems, was distributed after the second workshop (Moss et al., 2017) (Hazim et al., 2017). In this report, 1000W/m2 was picked as the standard force while air mass 1.5 was picked as the phantom organization, and both are yet utilized in ASTM guidelines for

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business sun-based test systems (Felix Schubert, and Daniel Spinner). Like the sun, powered radiation goes through the world's climate as in Figure 1 it is ingested, dispersed, or reflected by the accompanying cycles (Duffie & Beckman, 1991).

A segment of the sun-oriented radiation is dissipated when striking on atoms of air, water fume, and residue particles. The segment dispersed descending through the air showed up at the earth's surface as diffuse radiation. Another bit of sun-based radiation is consumed. The excess bit of the sun-powered radiation crosses through the air and arrives at the world's surface as immediate radiation. The present studied aims to show the different study of single pass solar air heater collector. The evaluation of solar collectors with smooth plate and with ribbed Indicates that the performance of the solar air collector relies upon substantially on the solar radiation.

Figure 1 shows the earth's energy budget according to (Schubert & Spinner, 2016).

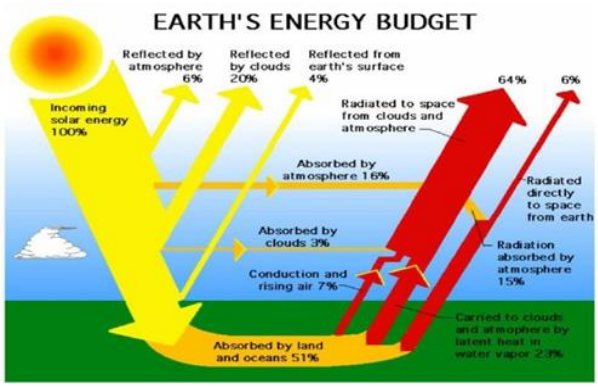

Figure 1: Earth's energy budget.

2. Thermal utilization of solar energy

The most well-known use of sun-based energy is warm use. In this, ordinarily there is an assortment gadget, which is straightforwardly presented to the sun based radiation. This can be an engrossing sort or thinking type. In the previous case, there is a dull surface presented to the sun, which assimilates radiation. Consumed energy is then moved to a liquid (like air or water), which is in touch with the safeguard. In the latter case sun, based radiation is concentrated to a point of convergence and the warmth energy is moved to the liquid. There are a few gadgets utilized for the immediate warm uses of sun-oriented energy. Portions of these are recorded underneath:

- Flat-plate collector.
- Concentrating collector.
- Space heating.
- Solar pond.
- Refrigeration and space cooling.
- Distillation.
- Cooling.
- Drying.
- Power generation.

3. Solar collector

One kind of exchanger that given internal energy from solar energy, and the type of the solar collector that utilized in numerous cutting-edge applications is solar air heater, such as engineering application, for heating purposes, in drying (drying agricultural crops, fruits and vegetables) and other application. Solar collectors used the direct sun to conduct tests, this means having many weather limitations, high wind, climate difference and other obstacles facing the research. To solve this problem many changes have been conducted until these experiments are conducted within environmental conditions suitable without the need for sunlight. For example, it was used photovoltaic cells, and other way by using solar simulator by lamps to simulate direct sunlight within laboratory conditions (Anon et al., 2013). Solar air heater collectors are normally separated into two sections relying upon the focus proportions: non-concentrating and concentrating (Bazzi et al., 2012).

Whereas the non-concentrating classified into

- Enhanced hybrid PVT collectors –Bifacial PVT (Photovoltaic thermal hybrid solar collector).
- Flat-plate collectors.
- Hybrid PVT Collectors.
- Moreover, concentrating collectors classified into:
- Parabolic trough collectors.
- Parabolic dish collectors.
- Heliostat field collectors.

4. Components of solar air heaters collector

4.1 Absorber Plate

Collectors are likewise developed with steel, aluminium, galvanized iron sheets, different thermoplastics, and metal particles. Copper is the

most part favoured due to its very high conductivity and protection from erosion. The absorber plate is the lower part of the solar air heater collector; it is the important part of the collector and ought to have high warm conductivity, satisfactory elastic and compressive strength, and great consumption opposition. The standard methodology for the manufacture of the absorber plate is to use a metal plate, such as aluminium, to prevent heat transfer to the outside, and to insulate the outside surface of the solar air heater collector. The plate absorbed the solar irradiance and heating the fluid or air passing through the collector. Figure 2 shows the absorber plate (Bazzi et al., 2012).

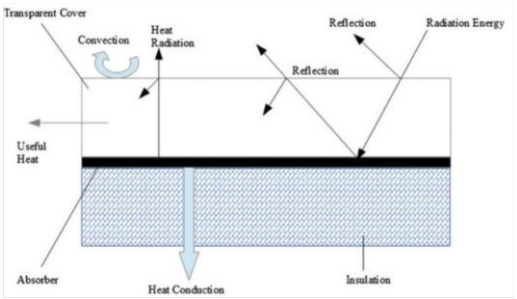

Figure 2: Absorber plate of SAH.

4.2 Cover Plate

It is the most effective part of the solar collector, due to the transmission of radiation and solar energy through it. In addition to its importance in transferring heat to the solar collector, it protects the internal parts of the solar collector from the influence of weather factors. The most widely used type of cover is glass. Tempered glass is more durable than other types and resists heat cycling as in Figure 3. When choosing glass for cover plates, it must be strong enough to withstand breakage due to wind or high heat. The mechanical strength is proportional to the square of the thickness. The minimum thickness of the glass used for solar heaters should be greater than 0.33 (Shukla et al., 1997). The main features of the cover are:

To transfer the maximum amount of solar radiation to the solar collector, especially to the absorption plate.

To reduce heat transfer from the absorption plate by radiation or convection to the outside environment.

Perhaps the most important reason to use the cover is to provide protection for the absorbent plate, especially when exposed to direct weather condition.

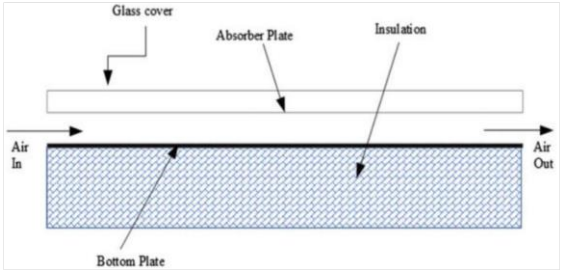

Figure 3: Glass cover of the SAH collector.

4.3 Insulation

The solar collector's absorber panel absorbs heat from the solar radiation but loses it due to conduction or convection. To prevent heat loss, the duct is insulated using insulating materials. The most common material used as insulators is glass wool. When choosing an insulator, the most important characteristic of it should be its high heat resistance as in Figure 4 and 6.

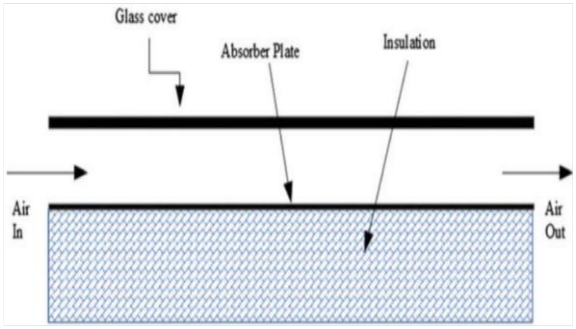

Figure 4: Insulation.

4. Solar collector applications

Solar air heater collector has been broadly applied in many engineering usages. Due to the absorption of solar radiation by the absorbent dental plate, as well as the transfer of the energy section added to the airflow along the channel to raise its temperature. Hence, this hot air can be used in many practical applications such as.

1) Household purposes

Different air collector has been manufacturing and utilized in cooling and warming cycle. Air collectors are utilized distinctly in effectively cooled and warmed structures. Air collectors are additionally utilized with desiccant beds for sun powered cooling. Warmth from air radiators can likewise be utilized to warm the generator of an ingestion climate control system for cooling reasons.

2) Agricultural purposes

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This is a promising space of utilization of sun oriented air radiators. For a non-industrial nation like Iraq, horticulture is the foundation of the economy (Sodha & Bansal, 1987). Significance of drying is applying to the extent the development of the economy is concerned. Backhanded drying of harvests is conceivable with the assistance of sun based air warmers. The primary benefit of this is the clean condition wherein it is dried. The possibility of tainting of food items with residue or microscopic organisms is less. In circuitous strategy for drying, hot air from sun-based air, gatherer is flowed through the yield to diminish its dampness content. The air can be flowed utilizing a fan or by common convection. Correspondingly, the warmers are called dynamic or aloof dryers. In uninvolved dryer, the warm air ascends through the air warmer and goes into the drying chamber because of the lightness impact.

3) Industrialized heating Application

The utilization of SAH collectors for modern applications has become widespread in recent years. In wood industry, hot air is utilized for preparing lumber. Because of plastic area, the plastic is processed using SAH collectors. On the other hand, the process of dehumidifying or drying agricultural crops is the most important application of solar air heaters.

In industries, SAH are attached to industrial applications based on industrial cogeneration. The use of SAH collectors in the industrial sector is increasing rapidly. (Korotky and Taslim, 1998) studied experimentally the heat transfer enhancement by using ribs as a turbulators on a channel. Staggered rib geometries for of (p/e) 8.5, 10, and 5 and different (e/Dh) of 0.25, 0.167 and 0.133 for warmed and unheated dividers of a channel. The results of the work reported that the heat transfer coefficient in case of rib turbulators was a lot more noteworthy than that for the area between the ribs. What's more, the lowest value of heat transfer coefficient was found at the pitch-to height proportion of the ribs (p/e) of 5. Warm execution diminished with the blockage proportion. (Ahn, 2001) did another experimental study on a rectangular channel to test the effect of impact of five unique states of ribs on the heat transfer and liquid stream attributes of the tempestuous stream. The test was done under constant condition such as rib pitch-to height ratio, rib heights to hydrodynamic ratios, and constant heat flux on the top surface of the rectangular channel. The values of (p/e) = 8, and (e/Dh) =0.0476 and the aspect ratio of the channel was 2.33. The geometries of ribs used in the study were square, triangular, circular and semi-circular. The results of the study showed that the highest heat transfer coefficient value was in case of triangular turbulators and the experiments found that the square ribs gave the maximum friction factor value.

Kabeel et al. (2016) experimentally investigated on the effect of V-shaped rib turbulators on the enhancement of the heat transfer of the flat plate SP-SAH collectors with a single glass cover. The tests was planned and tried under winning climate states of Tanta city (30°43′ N, 31° E), Egypt. The SAH collector was intended to be not difficult to supplant the safeguard plate starting with one then onto the next one, with MFR rates were 0.062, 0.028, and 0.009 kg/s. The exploratory outcomes showed that the greatest worth of outlet temperature of the v-folded plate sun-based air radiator was 5 and 3.5 °C more than that of level and finned plates when the mass stream rate was 0.062 kg/s, individually. In addition, it expanded to be 8 and 5.5 C when the mass stream rate was 0.009 kg/s. It is likewise demonstrated that the warm effectiveness of the v-ridged sun-based air radiator is 8-14.5% and 6-10.5% higher than that of the level and finned plate warmers, separately, when the mass stream rate was 0.062 kg/s under the thought about arrangements and working conditions. The test results additionally demonstrated that the convective warmth move coefficient of the v-layered warmer came to up to 1.64 and 1.36 occasions than that of the level and finned radiators, separately, when the stream rate was 0.062 kg/s.

Solanki et al. (2002) experimentally investigated on the solar air heater collector with inclined rib turbulators under constant heat flux as (1500 watt) and the effect inclined rib turbulators on heat transfer of fluid flow in the SAH. The ribs was placed on the absorber plate of the rectangular channel of solar collector. Different parameter was used in this study such as (relative roughness height of 0.02-0.034, Re 2500-18000, and flow attack angle (30º-90º) for a fixed relative pitch of 10. The result explain that the maximum enhancement was (2.83, 2.3) for fraction factor and Nu respectively at angle of attack (60º).

AME Momin et al. (2002) Experimentally studied the improved heat transfer with distinctive mathematical boundaries of V-ribs and stream of liquid for rectangular channel of solar air heater authority having V-ribs fixed on safeguard plate. The tendency approach of (60°) impacts the warmth move upgrade and the improvement in grating element and Nusselt number has been discovered to

be individually 2.83 and 2.3 occasions that of smooth channel. It was discovered that for relative ribbed stature proportion of 0.034 and tendency approach of 60°, the V-ribs improves the upsides of Nu by 1.14 and 2.30 occasions over slanted ribs and smooth safeguard plate case at Re of 17034.

Yang et al.(2009) made an experimental study to see how much the heat transfer coefficient is improved in a square channel with parallel ribs fixed at 45° where the ribs arrangement on two walls of the channel. The condition that was used in this study was (e/Dh) was (0.1-0.18), (p/e) ranged between (5-10) and the values of Re was (30,000 to 400,000). gave greater value of heat transfer coefficient despite the high-pressure drop. The results of the test work showed that a bigger (e/Dh) value and a more modest (p/e) value the bitter heat transfer coefficient enhancement in spite of the great pressing factor drop.

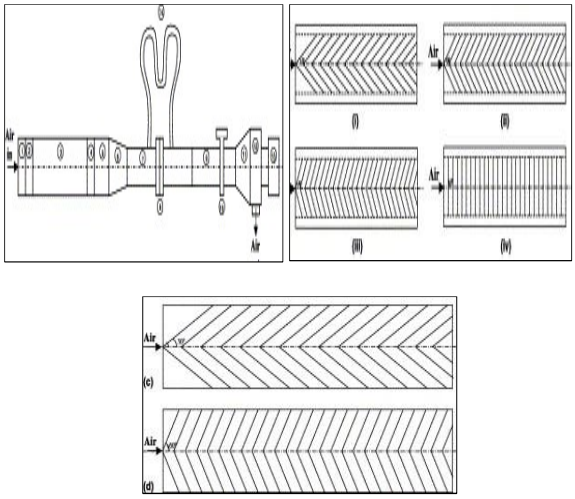

Figure 5: Solar collector with different type of ribs (Rallabandi et al., 2009).

Lanjewar et al. (2011) made an experimental study examination of SAH with ribs type of (W-ribs) to find the thermal and flow characteristics of the system. They were examined different geometric parameters like relative ribbed height, relative ribbed pitch, width to height ratio, and flow attack angle (α). The parameters were changed in the elected rate. From the consequences of stream perception, the blending impact of auxiliary streams was found in the halfway area between w-ribs. This was because of the pressing factor and speed contrasts across the section between the combining and veering sets of ribs. The warmth move in the area between ribs in the range shrewd course is likewise upgraded because of horizontal blending and auxiliary stream. The tendency point of - ribs affects the warmth move upgrade. The greatest improvement in the warmth move was found with the tendency point of 60°. In addition, the most extreme expansion in Nu was 2.21 occasions when contrasted with smooth channel at Re of 14000. Most extreme Nu acquired at relative ribbed stature of 0.0337 and with the tendency point of 60°.

The experimental investigation by Faridah et al. (2011) on solar air heater collectors with halogen lamps for internal testing. Twenty-three halogen lamps 500 w/230V used for simulation system, the halogen lamps was at constant height at (160) cm from the SAH. The size of solar air heater collector (SAH) was (120 x 53) cm, the maximum solar irradiation was (804W/m^2) and uniformity was and 6.9% at ambient temperature (27 to 30) ◦C. Their results showed that. It has been exhibited that the manufactured the simulator system, with the strategy of configurable lights exchanging, is fit for delivering repeatable scopes of irradiance for testing of solar air heater collector authority.

Shi et al. (2013) experimentally studied the improved heat transfer the and friction factor values of flow in 10 different rectangular channels roughed by ribs on two opposite surfaces. The aspect ratio of these channels was 1/4, 1/2, 1, 2 and 4. The ribs attack angle (α) was changed as values (30o, 45o, 60o and 90º). The value of Re ranged between (10,000-80,000), when the constant value of (p/e) =10. The maximum enhancement in the thermal efficiency was found at low MFR and the best enhancement in the heat transfer was found in case of ribs with (α =60º). Also, the maximum increase in friction factor values at the same angle (α =60º).

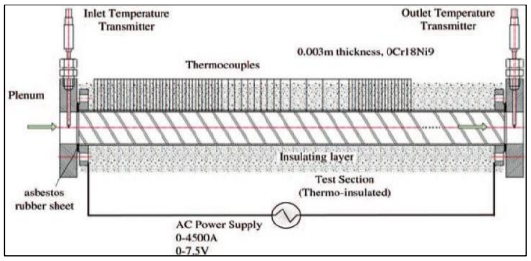

Figure 6: Solar collector with halogen lamp (Hussain et al., 2011).

Experiments were performed by Chamoli and Thakur (2014) with used V-down perforated ribbed in solar collector. Improvement in the thermal performance of V-down ribbed channel was found to be (20 -80) % as compared with smooth channel. The length of SAH is 2400mm and the section of test

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(350x 35) mm (width x depth), the baffled plate painted black and the system was under constant flux ($1000 W/m^2$). Maximum enhancement in the thermal efficiency was found at low MFR. Its effective efficiency was considerably lower compared to thermal efficiency at higher MFR due to higher pumping power at increased MFR.

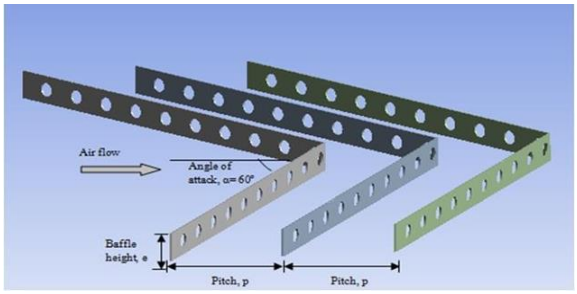

Figure 7: Solar collector with V-down rib (Chamoli & Thakur, 2014).

Additionally, by experimentally examination was applied to inspect the impact of the presence of ribs on heat move qualities by Chao et al. (2014) in a rectangular duct was cooled by ribs type of parallel. The duct was used with different parameter as Re was varied (3070-14800), (e/Dh) was 0.078 when the value of (p/e) was (8, 10 and 12), the angle of the rib was changed (45°, 60°,75°, 90°) and aspect ratio was fixed (W/H)= 3. The results showed that the great enhancement in heat transfer coefficient value became higher when the duct with inclined ribs. For 90° ribs at Re=14800 and (p/e) value (10 and 12) gave a found the middle value of warmth move on the rib roughened surface about 8.4% and 11.4% more than P/e=8, separately. For other slanted ribs at Re=14,800, the arrived at the midpoint of warmth move coefficients of 75°, 60° and 45° increment by 20.1%, 42.0% and 44.4% in contrasted with 90° rib point model.

Eren et al. (2015) played out a test examination to quantify the upgrade the warmth moves in a rectangular channel with punctured ribs mounted on the lower part of the channel. The warmth move and contact factor were tried under a tempestuous stream system by utilizing Reynolds numbers range from 5375 to 36362. Estimations are performed with rib pitch to rib stature proportion of (p/e) =12, and a rib tallness to the channel tallness proportion of e/H= 0.1. The presence of ribs delivered higher worth warmth move coefficients than the smooth channel. Results show a 34.1% increment in heat move because of the utilization of ribs.

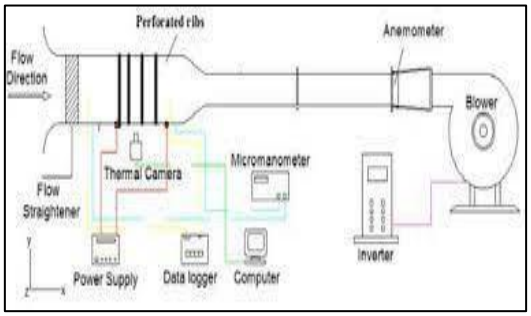

Figure 8: Solar collector with device (Eren et al., 2015).

Hanif et al. (2016) presented a similar investigation of the heat transfer estimations in a solar air heater with (1.7 m2) area. The solar collector was worked under a constant solar radiation (900 watt), the tests was done in 9th 2013. The purpose of this current study was to prepare the solar air heater collector for the draying and other processes that slept using the sun. It worked under a productivity of 7.5 to 21%. The warmth gathered by the air warmer was given to air streaming as a medium inside it. This hot air was given to a drying segment and water-warming tank for drying and water warming purposes. The drying segment gave a temperature in the scope of 40-50oC and mugginess of 1030% from 10:00 am to 3:00 pm. The water-warming tank furnishes heated water with a temperature of 35-45°C from 10:00 am to 5:00 pm. Moreover, the drying area was utilized to dry apples, onions and persimmons. Every one of the items showed a reliable dampness misfortune from them with an ideal drying rate. The two term remarkable model showed that every one of the three items dried have a decent relationship with drying time with R2 esteems higher than 0.90.

Figure 9: Solar collector with water warming tank (Hanif et al., 2016).

Gurav utekar et al. (2016) investigated performance analysis of solar air heater with inline

and punctured Wshape rib roughened safeguard plate for air warming application. investigation have been carried out by testing the collector under clear sky with available solar radiation intensity with variation in mass flow rate of air passing through collector ranging from 0.01484kg/sec to 0.01726kg/sec for three different absorber plates. Collector efficiency has been evaluated for plane absorber plate and compare with absorber plate having inline and staggered shape plate. It was found that instantaneous collector efficiency for staggered W-shape perforated fin roughened absorber plate solar collector is 18% greater than plain absorber plate solar air heater for MFR of 0.01726kg/sec, 12% higher than the absorber plate with inline W-shape rib case. Enhancement the efficiency of the solar air heater collector because increase in the turbulence of the air for staggered W-shape absorber plate solar collector.

In addition, Vaziri et al. (2016) did experimental work to investigate the advantage of utilizing various inner collector colours of perforated glazed SAH and unglazed transpired SAH with black coloured. Two PGSAHs having punctured Plexiglas coating and distinctive inside base tones were developed. The third sunlight based air warmer was an UTSAH where the top cover was dark shaded punctured sheet metal. The measurements of the openings on the Plexiglas covers and sheet metal cover were 3 mm and the pitch distance was 30 mm. No safeguard plates were utilized in PGSAHs, where punctured metal cover is the safeguard plate in the UTSAH. Added fans bring encompassing air into the authorities through the punctured Plexiglas in the PGSAHs. Essentially an additional fan brings encompassing air into the gatherer through the punctured metal in the UTSAH. The air mass stream rate was changed between (0.017 kg and s) and (0.036 kg /s). The most noteworthy efficiencies were accomplished at mass stream pace of (0.036 kg /s). The most noteworthy upsides of proficiency for dark, green, blue, red, violet, light yellow and white PGSAHs were, 85%, 84%, 76%, 65%, 61%, 54%, and 55% separately, while at a similar mass stream rate the greatest worth of effectiveness for the UTSAH was half.

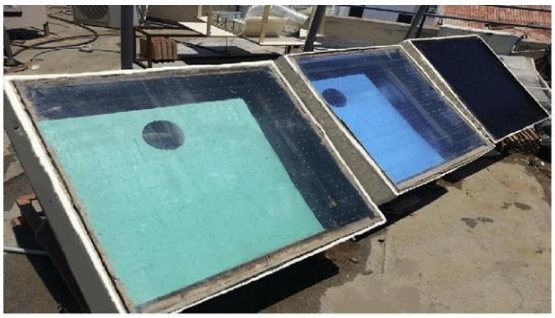

Figure 10: Types of solar heater collector (Vaziri et al., 2015)

Kumar et al. (2016) presented heat transfer and fluid flow characteristics in a solar air heater (SAH) channel with multi-V shaped perforated ribbed. The stream entry has a perspective proportion of 10. The relative rib stature was 0.6, relative pitch was 8.0, relative rib position was 0.42, assault point of stream was 60°, and rib open region proportion was 12%. The outcomes were in better concurrence with the test information for the reach considered in the examination. Multi-V punctured ribbed were appeared to have great largely warm execution when contrasted with different ribs in a rectangular channel. The warm exhibition showed the extraordinary worth at the relative rib width of 5.

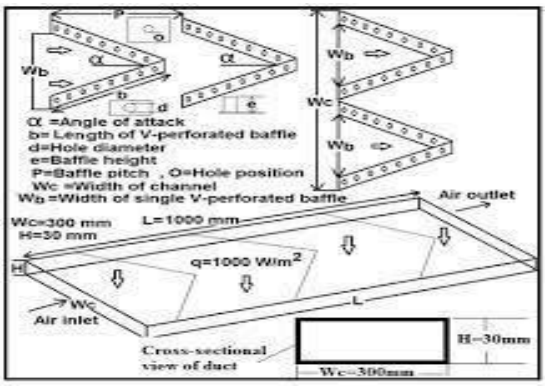

Figure 11: Solar air heater collector Multi-V (Kumar and Kim, 2016)

On other hand, Kumar et al. (2016) experimentally studied the effect of change in the angle of attack. The type of rib was used in this study was a discrete V-shaped developed in a rectangular channel. The rib divider was continually warmed and the other three dividers of the channel were kept protected. The experimentations were led to gather the information on friction factor and Nu by different Re (3000 to 21,000) and attack angle was (30° - 70°), the other condition that was used in this work (*Pb*/H

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= 1), (Hb/H =1/2), (gw/Hb = 3/2) and (Dd/Lv = 0.67). The results have shown that the case of V-ribs when fixed at α= 60° and Re 3,000 yields the maximum thermal performance, the friction factor and Nu was found 5.9 and 4.2, respectively. Discrete V-design confound has improved warm execution when contrasted with other confuse shapes' rectangular channel.

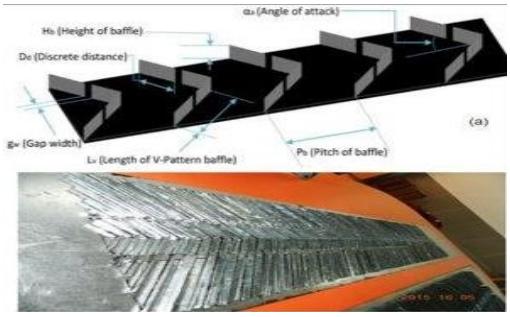

Figure 12: Flat plate discrete V-shaped (Mohammadi & Sabzpooshani, 2013).

Moss et al. (2017) studied the thermal performance of the solar collector with wire stainless mesh, MFR was fixed at 0.037 kg/s and PPI was ranged (4, 8, 12). A halogen lamps solar simulator system has been designed and manufactured for workout collector with dimension (1 x 0.7 x 0.1) m indoor. Four halogens with (1,500 W) was used in the study where the maximum solar radiance was 980.4W/m2 with uniformity as (6.84%) at suitable height 70cm. It was found that the performance of the collector was increased in the case of wire mesh by 65% and outlet temperature was 41.4◦C compared with a case without mesh.

Figure 13: A halogen lamps solar simulator (Moss et al., 2017).

Hazim Moria et al. (2017) studied experimentally the turbulent flow and stream structure and heat transfer enhancement of a solar simulator system. The solar simulator was manufactured with 8-halogen lamps development for indoor testing purposes. The solar simulator device was manufacture d by using eight halogen lamps 500 Watt /220 V. Each 4-lamps arranged in series, and afterward the two gatherings associated in parallel. The halogen lamps was fixed in the hubs of a 2x4 equidistant lattice, oppositely to one another. The solar irradiance created by the eighthalogen lamps estimated with a pyrometer at various distances among reflectors and various distances up to the objective region. It was concluded that the consistency and solar radiation fitting when the distance between the reflectors was 15 cm, and the distance to the objective plane was somewhere in the range of 20 and 40 cm.

Figure 14: Solar simulator with halogen lamp (Moria et al., 2017).

Gonzalez (2017) manufactured a low-cost LED-based solar simulator by comparing LED to sunlight and halogen using the following parameters: irradiance and uniformity. The results shows the LED produced lower radiance compared to the halogen lamps for a given distance due to higher power exhaustion. Furthermore, the halogen showed perfect uniformity at large space the while LED showed perfect uniformity for all space. The characteristic curves of a student PV module were measured. At a given irradiance level, the PV module yield was comparable for LED and the sun, while the halogen performed ineffectively because of its wealth in high frequency, low energy photons. Chauhan et al. (2018) exploratory researched of the solar air heater collector with various type of blockage arrangements as roughness elements employed over one wall. The warmth move and

liquid stream qualities in an air section was tested with Re (3000-18000). During the test, assessment air was gone through the test section under a uniform divider heat transition of the warmed divider plate. During the exploratory examination creator tracked down that the V-type punctured blockage gave better performance of the SAH collectors execution as contrasted and other sort blockage air entry.

Sabzpooshani and Mohammadi (2013) experimentally investigated on the parametric investigation of the balances and perplexes of SP-SAH. The impact of MFR and sunlight based radiation force were analyzed. In examination with the basic air radiator, the power source temperature, valuable energy, and effectiveness expanded because of joining blades and bewilders. Expanding the wind current rate decreases the power source temperature forcefully. Also, expanding the balances and confounds boundaries impact the power source temperature when the mass stream rate expanded over 0.03 kg/s. The outcomes likewise showed that expanding the width of balances and perplexes and diminishing the distance between them prompted the improvement of the exhibition however further expanding of them builds the necessary siphon work and thus decreasing the upgrade. The confuse width is a vital boundary, particularly, at higher mass stream rates, and should be painstakingly chosen due to higher pressing factor drop. Choosing ideal boundaries of blades also, perplexes were discovered to be dubious in all mass stream rates, yet can be assessed for each mass stream rate.

Alam et al. (2014) experimentally investigated the effect of geometrical parameters of the V-shaped perforated blocks on heat and stream qualities of solar air heater collector. Broad test information was gathered on heat move and contact qualities as capacity of mathematical boundaries of these squares, to be specific, relative stature (e/H), open region proportion (b) and relative pitch proportion (P/e). They presumed that Nusselt number and erosion factor are unequivocally relied upon the open region proportion, relative blockage stature and relative pitch proportion.

An experimental study presented by Hamed et al. (2018) (30) to investigate the thermal performance in a (SPSAH) with 19-longitudinal fins. The fins were utilized to build the warmth move region and to convey the wind stream consistently in the channel. Trials were directed at three different statures of blades (3, 5, and 8 cm) to explore the impact of the tallness. The passage district was covered with glass cover rather than dark or steel cover. Furthermore, manage edges were set in the passage area to guarantee great air circulation over the safeguard surface. The examinations were performed at four different ṁ shifted between 0.013 kg/s and 0.04 kg/s. For each instance of study, the presentation of the altered SAH was contrasted and customary one. The greatest every day productivity of the customary finned SAH was 43.1% at 0.04 kg/s and 8 cm balances' stature. Altering the passage district prompted great upgrade in both yield temperature and effectiveness. For the altered finned SAH, the most noteworthy every day productivity was 57% at 0.04 kg/s with balances' stature of 8 cm. While for the customary SAH, the most elevated every day effectiveness was around 32 %.

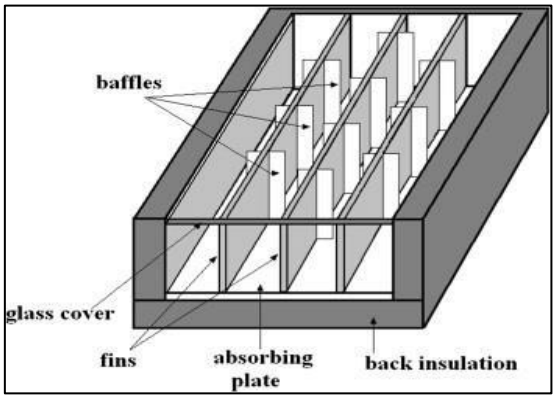

Figure 15: SAH collector with baffles (Mohammadi & Sabzpooshani, 2013).

Saravanakumar and Mayilsamy (2010) studied the impact of a thermal storages on the thermal efficiency of the solar air heater collector and compare the result with case of without thermal storages. The solar air heater area was (2m x1m) with single glass cover (5mm). Hole (100-mm) between safeguard and protection is loaded up with heat stockpiling materials with iron pieces to store heat during daylight hours and to acquire hot air during off daylight hours. SAH is shifted to 25°as for even 14. Framework is situated to point toward the south to augment sun based radiation episode on sun-based authority. Based on estimations, Aliyar, Pollachi Taulk (scope 10.39°N, longitude 77.03°E), had 11 h 30 min of daylight, however potential daylight term is 8 h each day as it were. The experimental result show that the thermal efficiency of the solar collector with thermal storages was (10-20) % greater than without.

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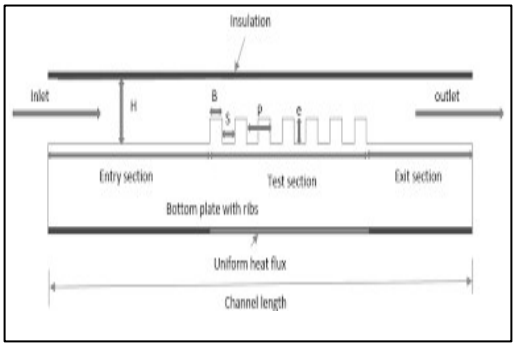

Figure 16: Single pass solar air heater collector with rib (Sriromreun, 2015).

Sampath et al. (2009) studied numerically by using CFD commercial Fluent the heat performance of solar air heater collector for different rib width and spacing. The ribs oriented at 90 degrees. This study intended the heat transfer coefficients and friction losses. The perspective proportions (W/H) 1, 2, and 4 were utilized for the investigation. Ribs were situated on inverse dividers, further, the width of the rib and rib dispersing contrasts while the rib tallness is kept steady. The pitch proportion (P/e) of 10 and 20 and the rib width to the tallness of the rib proportions varied (w/e) from 1/8 to 14 were thought of. This investigation applied Re value 10,000, 30,000, and 60,000. The outcomes achieved that the collector performance increased when the width of the rib diminished. The ideal cooling design was acquired by the joined impact of rib width, rib dividing, and stream boundaries. Furthermore, (p/e) = 10 delivers a superior outcome for heat move rate than for (p/e)=20.

Figure 17: Solar air heater collector for different rib width and spacing with solar panel (Kabeel et al., 2018).

Kumar et al. (2016) reported the heat transfer and fluid flow characteristics in solar collector channel with ribbed absorber plate. The counterfeit harshness of the rectangular duct was as a slim round wire in discrete multi V-design rib calculations. The impact of this math on heat move, liquid stream, and execution expansion was researched utilizing the CFD method. The thermo-pressure driven execution was discovered to be the awesome the discrete width proportion of 1.0. A discrete multi V-design rib joined with dimple staggered ribs additionally would be advised to by and large warm execution contrasted with other rib shapes.

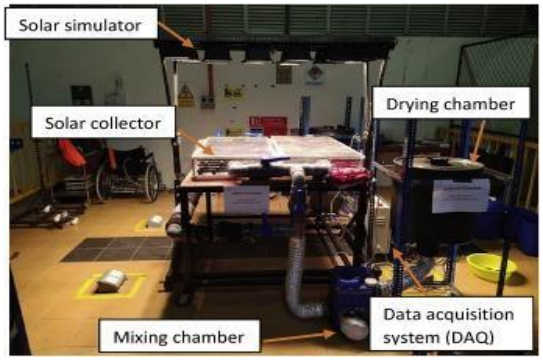

Figure 18: Solar collector channel with ribbed absorber plate under simulation (Razak, 2017).

Boonloi and Jedsadaratanachai (2017) numerically study on the laminar flow in a square duct of a SAH collectors and study the effect of geometrical parameters of the V-shaped on heat move and stream qualities a duct of solar collector. The V-wavy plate is a blend of the vortex generators between V-shaped astound and wavy surface. The analysts tracked down that the V-shaped plate gives the warmth move rate and productivity near the V-shaped. The creation and upkeep of the V-shaped plate are more advantageous than the V-shaped perplex. The ideal stream assault point of the V-shaped plate in the warmth exchanger channel for the laminar system was closed.

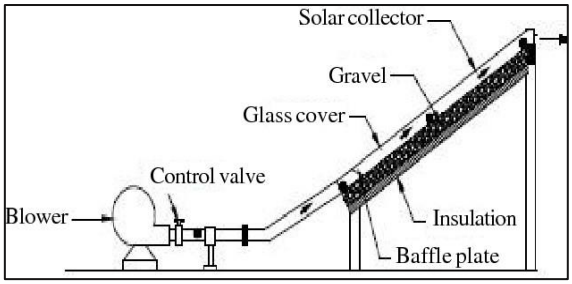

Figure 19: Solar air heater collector with baffle plate (Sampath, 2009).

Handoyo et al. (2016) described the result of the numerical studies of obstacles' spacing inserted in a

v-corrugated duct of a Solar collector. From numerical examinations in a v-layered conduit, they found that discharge among obstructions and high speed in the hole among hindrances and safeguard plate causes the stream turned out to be more tempestuous and improved the convection heat move between the air and the safeguard plate. Hence, when it is applied to SAH, it will improve its effectiveness however increment the gaseous tension drop.

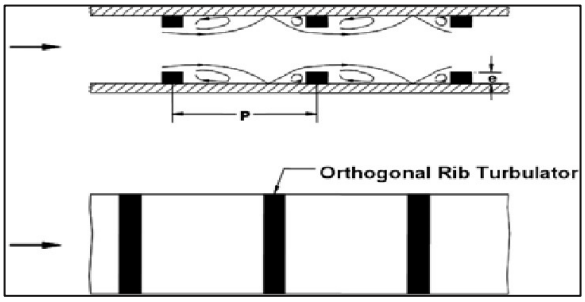

Figure 20: Orthogonal rib turbulators (Kumar & Kim, 2016)

Singh and Bhushan (2010) announced CFD based examination to contemplate impact of harshness component pitch on heat move and rubbing qualities. The calculation of the unpleasantness component. The examination covered a Reynolds number a scope of 4000-16000, relative unpleasantness pitch (p/e) from 7.5-10.7 for fixed relative harshness stature (e/D) of 0.029. It was seen that roughened safeguard plate upgrades heat move coefficient at the expense of friction penalty. Creator likewise created Nusselt number and Friction factor relationships by utilizing the information produced under CFD based examination.

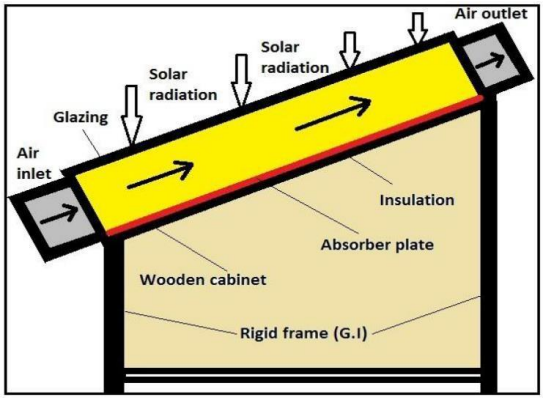

Figure 21: Solar collector fixed on rigid frame (Promvonge & Changcharoen, 2011).

Rezazadeh and Asaadi (2018) the effect different parameter was studied numerically in this study (angle of attack, ribs height, Re, and arrangement of the ribs on the absorber plate of the duct. The study was showed that when the rib height and Re increase the efficiency and heat transfer increased. In addition, the ribs attack angle (α= 60°) was given more enhancement in heat transfer. They additionally reasoned that scaled down channels with both rectangular and trapezoidal ribs created better outcomes for heat move and liquid execution than a little channel with rectangular ribs.

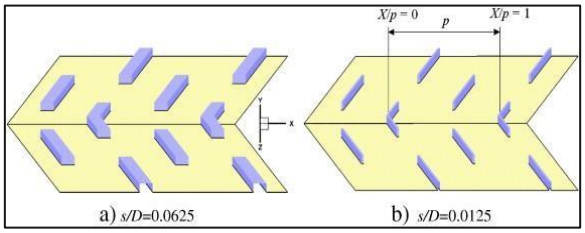

Figure 22: rectangular and trapezoidal ribs (Boonloi & Jedsadaratanachai, 2017).

Elwekeel et al. (2012) performed numerical studies to test the heat enhancement of a SAH collectors fitted with different ribs arrangement in lower absorber plate of the collector. Square ad trapezoidal ribs was used in this study fixed only on the bottom surface with using different fluids. Seven ribs were simulated. Constant flux as (15000 W/m^2), the mass flow rate at the inlet was 0.0269 kg/s, and the inlet saturated temperature was 388 K. The investigation applied with the coolant fluids like air, steam. The shear pressure transport (SST) disturbance model was picked by looking at the forecasts of different choppiness models with the test results. The results show that for all coolant fluids the trapezoidal ribs had the highest values heat transfer coefficient.

Also by using ANSYS-FLUENT 6.3 CFD code, Bagabir et al. (2013) presented a numerical examination of heat qualities with a fierce stream for a ribbed square channel collector. Re based on the conduit water driven distance across and differed from 104 to 4 x 104. The ribs impacts shape and direction on pressure drop and warmth move in the pipe were tried for six diverse rib courses of action. Ribs were orchestrated of 45◦ slanted and 45◦ V-shaped in inline and staggered plans of the top and lower part of the channel. The outcomes appeared overall, the upgrade of warmth move in the channel with two inverse ribbed dividers was 230−580 % more noteworthy than the smooth channel. The increment of warmth move was related with

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augmented grating misfortune shifted from (2.0 to 6.2) times over the smooth channel. Moreover, the slanted and Vformed rib that organized in an inline way identified warmth move upgrade of around 17-50% more noteworthy than that for the 90◦ rib. While the pressing factor misfortune decreased at around 4-38%.

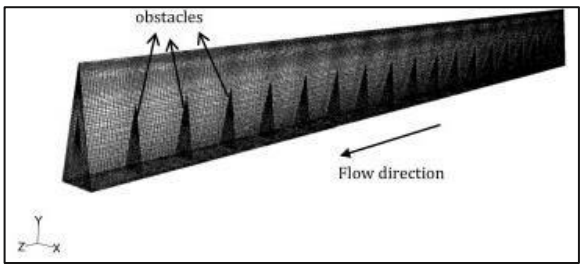

Figure 23: 45◦ slanted and 45◦ V-shaped in inline and staggered plans of the top and lower part of the channel. (Soi et al., 2010).

Kumar et al. (2014) made a numerical examination of a solar collector with ribs to enhance heat transfer of the collector. This work used a collector with square duct fitted with two type of ribs turbulators (rectangular and elliptical) punctured ribs put toward stream on inverse dividers. The Nusselt number is achieved by changing the Reynolds number from 8500 to 14500. The examination made utilizing GAMBIT 2.4.6 programming. Mathematical re-enactments were performed using the CFD programming ANSYS 14.5 FLUENT. Moreover, the reproductions used the shear-stress transport (SST) k-ω model as the most proficient model. For the diverse scope of Reynolds number that tried, the ribs that had intermittently game plan gave great outcome contrasted and the ribs that haphazardly orchestrated in light of the fact that it made more choppiness than the ribs that arbitrarily masterminded. Moreover, the outcomes showed that Nusselt numbers were expanded with the expansion of the with Reynolds numbers.

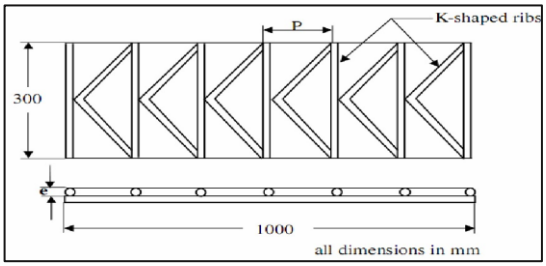

Figure 24: Two type of ribs turbulators (rectangular and elliptical) in a square duct. (Rezazadeh & Pourmahmoud, 2018).

Deviboga and Jayavel (2014) Studied numerically the effect of various shapes of ribs (triangular, rectangular, and semi-circular) on the heat and stream field in a SAH collector. Standard k-ε disturbance model and improvement divider treatment worked to deliver the re-enactments. The inflow Reynolds number was changed from 5000 to 10000. Every one of the ribs were separated in channels with a proportion of pitch to tallness (p/e) = 4, width to stature proportion (W/H) of 2. Energy conditions and x-force with advantageous limit conditions at the channel, power source and confined dividers are settled by limited volume technique using the stream solver, Fluent. The outcomes announced that for the considered Reynolds number, the normal Nusselt number of the warmed divider in the channel with three-sided ribs is the biggest. In addition, they tracked down that the three-sided ribs with a direction point of 30◦ had the most elevated heat transfer.

Farooqui (2015) performed computational fluid dynamics (CFD) simulations to calculate the heat transferrin of a solar collector with rectangular channel. The simulation used ANSYS FLUENT 15.0. The study concerned with the influence of rectangular ribs on the heat transfer of the solar collector. The absorber plat of the collector consisted of ribs. The study included a comparison between the aftereffects of the great angle proportion and square ribs orchestrated in three models, specifically, single divider course of action, staggered and inline game plan. Plans were in two inverse divider. The Reynolds number differed from 5000-24000 with fixed rib pitch (p) and fixed tallness (e) values. The outcomes uncovered that the presence of ribs prompted an impressive increase in heat move when contrasted with the smooth channel. The outcomes revealed the slight ribs yielded more noteworthy worth of execution than the squared ribs. The flimsy inline ribs gave the greatest warm exhibition whose warmth move coefficient was 1.83 occasions smooth channel's heat transfer coefficient values.

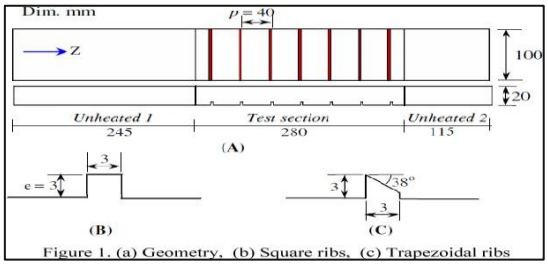

Figure 25: rectangular ribs on the heat transfer of the solar collector (Bagabir et al., 2013).

Also, by using ANSYS Workbench software 14.5 Bhola (2017) performed the numerical simulation for fraction factor and heat transfer for a ribbed channel with turbulent flow, under steady heat flux applied at the base plate, and the upper plate was protected. Three qualities chose of the proportions of ribs length to remove between the two plates (B/H) 0.5, 0.7, and 1. The fundamental target of the work performed was to track down the best tallness of ribs to the stature of the channel proportion under comparative limit conditions. The result was discovered that Nusselt number had been expanded by about 143% to 216% by utilization of ribs. In addition, greatest improvement was appeared by ribs length to separate between the two plates proportion (B/H) of 0.75 with an augmentation of 149%, 160% and 216% for particular Reynolds number. The addition was about 6% to 15% when contrasted with other two proportion of ribs length to separate between the two plates (B/H).

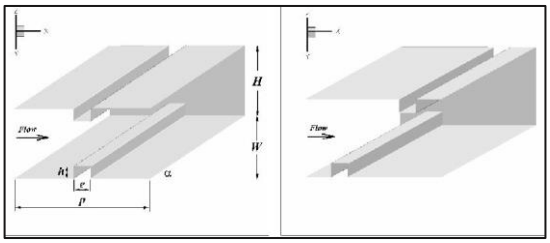

Figure 26: rectangular ribs in the channel (Kumar & Prabhakar, 2014)**.**

Sriromreun (2018) studied numerically the liquid stream attributes and heat transfer in a rectangular channel of a solar air heater collector with a combined staggered rib. The inclined cylinder V-shaped rib used in this work. The heat and the pressing factor drop addressed in term of Nusselt number (Nu) and Friction factor (f). The connection of Nu with f esteems was broke down to achieve the factor of the warm exhibition upgrade. The channel was re-enacted at the stature (H) of 30 mm and width (W) of 300 mm and furthermore with rib-to channel-tallness proportions (e/H) at 0.1, 0.2, and 0.3 with steady warmth transition on the base surface of the inspected area. The approach (α) at 30°. Reynolds number (Re) went from 12,681 to 35,000. The outcomes showed that the increment of e/H caused a high co-pivoting of the stream subsequently; the expanding e/H gave higher upsides of Nusselt number and the Thermal execution upgrade factor. What's more, Result showed that higher worth of Reynolds number caused an increment in the Nusselt number and abatement in warm execution upgrade. A numerical study presented by Rawat (2018) to analyse the thermos-hydraulic performance for the solar air heater with rib turbulators located at right angles 90o. The numerical values of warmth move and the grating component were determined. The rib pitch to the tallness of rib proportions (p/e) were changed as 3, 6, 9 and 12. The tendency points were changed from 45˚ to 90˚ in a stage of 15 in this manner prompted various states of ribs for example right-calculated triangle, square and trapezoidal ribs. The investigation had been finished with shifting Reynolds numbers 4000, 8000, 12,000, 16,000 respectively. A right triangular shaped rib with p/e= 9 found best for thermo-hydraulic performance in comparison with the square rib.

Velmurugan and Kalaivanan (2015) conducted another experimental, numerical work to study the performance of four type of a solar air heater collector (SPFP-SAH), (RPDP-SAH), (FPDP-SAH), and (WMDP-SAH) worked with various MFR and solar irradiance. The scientific arrangement of the energy balance conditions for different components of the SPFPSAH, RPDPSAH, FPDPSAH and WMDPSAH is resolved utilizing a MATLAB 8.1 program and related with exploratory discoveries. The scientific and exploratory outcomes show that the energy and exergy execution of WMDPSAH is better than FPDPSAH, RPDPSAH and SPFPSAH. The pressing factor drop of WMDPSAH is higher than that of FPDPSAH, RPDPSAH and SPFPSAH. From the financial examination, WMDPSAH is found monetarily reasonable inside the picked conditions contrasted and FPDPSAH and RPDPSAH. The insightful and exploratory outcomes are in genuinely acceptable understanding.

Tang and Zhu (2012) were studied the heat transfer enhanced of a solar air heater collector numerically and experimentally with turbulent water stream in a with the presence of irregular crossed ribs and furrows. The investigation inspected the warmth move execution and grating component in ribbed channels. The exploratory work revealed that the mostly thermo-water driven execution for the ribbed-notched channel was brought by 10%–13.6% up in contrasted with the ribbed channel. The mathematical examination on the impacts of a few rib pitches and rib points on heat move attributes and grating component in the ribbed notched channel was executed by utilizing Fluent with SST k-ω choppiness model. The outcomes detailed that the case for rib point of 45° gave the most extreme generally thermos-water powered execution, 18%–36% more prominent than rib point of 0°.

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An experimental and numerical study presented by Smaisim et al. (2018) to improve the performance of the solar air heater collector. a laminar flow of the forced convection heat transfer by testing Reynolds numbers between 500 and 2000. Rectangular rib surfaces are used, and different parameters of ribs have been examined number of (continuous and discrete) ribs. The channel that examined in this investigation has a length to water powered width proportion (L/Dh) is 3, proportions of rib stature to pressure driven measurement (e/Dh) of 0.06, the pitch proportion (p/e) of 10, and the approach of 90°. At the comparative condition, Nusselt numbers and the contact factor contrasted and the qualities acquired for the smooth channel. In mathematical work, boundaries have been acquired by utilizing the business ANSYS CFX 14.0. This study showed that the warmth moves improved by raising the harshness tallness at fixed relative unpleasantness pitch or by diminishing the unpleasantness pitch at fixed harshness stature.

Also, by experimental and numerical investigation Ho et al. (2014) (50) tested the performance of a SAH collectors included with twofold pass just as balances and bewilders with reused. The results of the experimental teste digress by 1.5–23% the hypothetical forecasts. The exhibition of SAHs with various plans are analysed, including the SP-SAH, DP-SAH with reuse, fined twofold pass with reused, and fined besides confused twofold pass with reuse. In view of both hypothetical and test results, the authority effectiveness of the fined in addition to perplexed twofold pass with reused configuration is a lot higher than different plans under various reflux proportions and mass stream rates. The ideal reflux proportion of the fined in addition to confused twofold pass configuration is about 0.5 while thinking about both the authority proficiency and the siphoning power necessity.

5. Conclusions

Heat transfer enhancement is one of the more important issues of saving energies and compact styling for chemical and mechanical machines. In the current years, considerable assurance has been located on the intensified works to improve the heat transfer because of the economic motivations have led to the improved endeavours aimed at creating more effective heat exchange apparatus through the intensification of heat transfer.

This study discussed and reported a review of several previous studies that focused on the enhancement of the thermal performance of the solar air heater collector. Different methods that effect on the performance of the solar collector such as changing in a solar radiation, using the rib turbulators, thermal storage and other.

In case of ribs turbulators there are many parameters of ribs have important effect on the enhancement of the SAH-performance such as pitch ratios, height ratios, shapes and inclination angles with or without perforating. The authors tested all these factors and their effect on enhancement of the performance. In laminar and turbulent flow regions.

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