Solar Air Heater and its Classification – A Review

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Abstract*—A solar air heater is a device that transfers radiant energy from a distant source to air. Crop drying, heating systems, and re-generating dehumidification agents are all possible uses for solar air heaters. Classifying solar air heaters correctly is a difficult undertaking. There are several configurations, some of which are constructed empirically. They are divided into three categories based on their style of operation: active, hybrids, and passively. The purpose of this paper is to provide an overview of solar air heaters and their classifications.

***Keywords*—Solar Energy, SAH, Flat plate SAH**

I. INTRODUCTION

All sources of energy originate from solar energy. The importance of energy in our society is increasing in order to maintain a high standard of living and to keep the rest of our economic going smoothly. In the twenty-first century, some renewable energy sources are in use, but many more are currently being developed. Solar air heaters (SAHs) were extensively utilized as heat exchangers in solar energy applications [1]. One of the most common solar thermal systems is air heat, which is used for space heating as well as processing heaters such as washing, desalination, crop drying, and other drying operations. Using traditional energy for this operation will raise the expense of the procedure while also polluting the environment. The use of solar energy for air heaters lowers the system's operating costs and reduces the use of conventional sources. This study intends to bring together the effort of researchers working on SAH to identify ways to offer it in the form of strong programs that can be used, and therefore to boost efficiency used in design and development in the current setting. Due to the huge amount of shapes and empiric constructions, classifying solar air heaters is difficult. A solar air heater is a device that transfers irradiance from a remote point to air. Solar air heaters could be used for a variety of things, including crop drying, heating systems, marine items, and heaters a building to keep it warm in the winter.

Energy is available in a variety of forms and plays an important role in global economic and technological development. The pace of energy consumption increased as the global population grew along with expanding material needs. As long as the earth's designated energy supplies are exploitable, the continual increase in power use characteristics of the previous 50–100 years cannot continue indefinitely. On the other side, environmental degradation caused by the use of fossil fuels is a threat to human life. The development of renewable energy sources has gained relevance in light of the world's decreasing fossil fuel resources and environmental problems. Solar energy stands out as a prominent source of energy for meeting demand among various options. Due to its enormous potential, it is seen as a resolute renewable source. Solar radiation, which is free and non-polluting, supplies a limitless and non-polluting fuel reservoir [2]. Solar thermal collectors are the simplest way of converting solar energy into thermal energy for use in heating purposes. Flat plates collecting, such as solar water heating system and solar air heaters, are being used to heat air and water, respectively. In compared to solar water heaters, solar air heaters are smaller and less complex. Solar air heaters are easier to make using less expensive materials and to use than solar water heaters. Solar air heaters generate hot air for industry or farmer-level dryer applications utilizing free solar energy rather than conventional fuels such as electrical, diesel, LPG, firewood, coal, and so on. However, it might be used in conjunction with current traditional drying systems that use conventional fuels, such as tray tumble dryers, tunnel tumble dryers, belt driers, FBD driers, and bin tumble dryers, to reduce fuel use. Because of the low heat transfer capacity between the absorber surface and the fluid flowing through the ducts, the thermo efficiency of the solar air heater is low.

SAHs have been utilized in a variety of applications to save energy, particularly in applications that need low to moderate air temperatures. Space heating, textiles, maritime items, solar water desalination, and crop drying are all uses where they work well [3]. SAHs provide a number of advantages over liquids heaters, including the avoidance of difficulties like as freeze or stagnation, leakage, damages, and the danger of an environmental and health hazard from the heat transfer fluid. Furthermore, they lower the application's power consumption expenditures. SAHs, on the other hand, are limited by their low temperature region, low specific heat capacity in contrast to water (air=0.0003 kW h/m3 K; water=1.16 kW h/m3 K), and noise from the fan & open air ducts.

II. CLASSIFICATION OF SOLAR AIR HEATER

Active, hybrid, and passive SAHs are the three types of SAHs. The tracking axis, energy storage, expanded surface, and amount of covers are all used to classify solar air heaters. Hot air is created at several locations and routed to the end use in inactive solar air heating devices. In active SAH, heat storage material are widely used to generate heated air during the night. Passive SAHs, on either hand, are typically used during the day. Active solar panels are simple to construct since they use pushed air, but they are more expensive to build than passive solar devices. In another way, SAHs can be divided into single-pass and the double with or without thermal mass depending on the number of air passages. Air flows in one direction from the air input to the air exit in a single-pass air solar heaters, either above or below the absorber surface, as

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shown in Fig. 1. Air passes via two tubes in the double air solar heater.

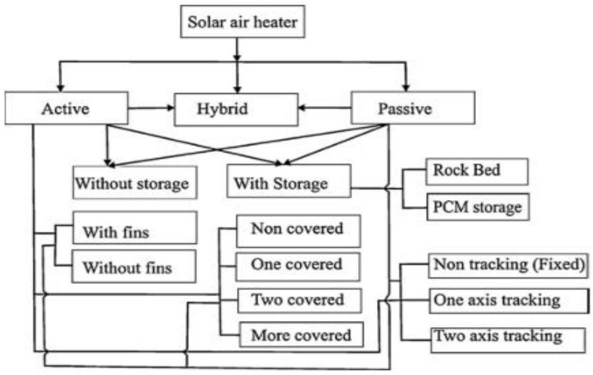

Fig.1. Classification of Solar Air Heater

Solar air warmers are the most extensively utilized collecting devices due to their inherent simplicity. Solar air heater are mostly used for space heating, timber conditioning, and industrial product cures, but they could also be used to cure/dry concrete/clay structural components. Because of its low materials and cost requirements, the solar air heater is a popular choice amongst solar heating systems [4].

A solar air heater (SAH) is a device that captures solar energy using an absorbent surface and extracts the heat energy with air moving over it. SAH is the most cost-effective method of converting solar energy and is utilized in a variety of applications including as room heaters, crop drying, and other industrial purposes. A standard SAH is uncomplicated in design and takes little upkeep. Furthermore, due to the creation of a laminar sublayer, they have poor heat transmission between both the absorbers and the fluid, resulting in a decreased efficiency [5]. By interrupting the laminar sublayer and producing turbulent near to the absorber plate with artificial roughness, the heat transfer coefficient can be greatly enhanced. However, this comes at the expense of increased pressure loss, which increases pumps energy requirements. One of the most easy and efficient methods for heat transfer enhancement is the employment of repeating ribs as roughness components beneath the absorber. To date, a large number of experimental studies as well as a few Computational Fluid Dynamics (CFD) studies have been published to assess the impact of rough surfaces on the thermally and frictional performances of rough surfaces SAH ducts.

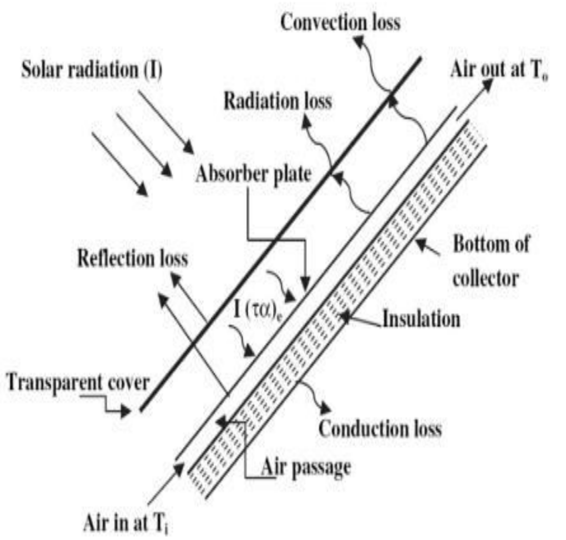

Fig 2. Conventional Flat Plate Solar Air Heater [5]

The fundamental disadvantage of solar air heating technology is the same as that of solar–thermal technology for producing home hot water: it does not work in synchronization with seasonal energy consumption. Even if the vertical orientation of the solar collector augments wintertime productivity and partially compensates for the season offsets, the availability of solar radiation decreases as the demand for hot air rises in the winter [6]. However, on the cloudiest days, the solar air collectors would not even turn on.

III. CLASSIFICATION ON THE BASIS OF ABSORBING SURFACE

Simple flat-plate collector: It is the most basic and often used collector. It consists of one or two glazings over a flat plate backed by insulating in its most basic form. As can be seen in figure 2, the air flow direction can be either above or below the absorber surface [7].

Finned-plate collector: This is a modified form of the kind collector, in which the heat exchange efficiency is improved by adding fins to the flat plate absorbers, and the surfaces is made directionally selected in some designs. In most cases, the fins are found in the passage of air.

Corrugated-plate collector: This is a version of the flat-plate collector wherein the absorbers is corrugated in rounder or V-shaped troughs. This provides a large surface area for heat exchange and may allow the surface to be directionally selected.

Matrix collector: An absorbent matrix in this design is a plates, cotton gauze, or loosely packed porous material. This sort of collectors has a high heat transference to volume ratio and, depending on the geometry, reduced frictional forces.

Overlapped transparent plate collector: This sort of collector is made up of a staggering array of partially darkened transparency panels. Between the overlapping panels are indeed the air flow pathways.

Transpiration collector: A modification of type (3.4), the transpiration or porous bed design eliminates the backing and back absorption. Air enters immediately beneath the innermost covering and flow down thru the porous bed and into the distributing ductwork.

In contrast to a passive system, a solar air heater is an active system. Heat-absorbing architectural substances and direction of the building that needs to take full advantage of southern exposure are used in passive solar systems. Solar panels gather solar energy, as well as fans keep moving it to a various location in active solar systems.

Enabling sun's rays into a heated space via south facing windows can be as simple as passive solar gathering. The thermal energy will be stored in the space's construction materials. The natural convective motion of heated air is used by passive solar collectors (Figure 3) to thermal transfer from the solar collector into the tower. The air in between straightforward glazing as well as the dark metal absorber is heated up and increases whenever the light from the sun is strong enough. This hot air enters the building throughout a slot in the wall at the highest point of the structure. Cool building air enters the solar collector through a slot close the bottom of the wall, resuming the cycle.

Fig 3. Passive Solar Collector Wall

A passive solar wall works year-round, day as well as night, without the use of fans or controls. Whenever the sun is shining in the late fall, cold weather, and beginning of spring, the wall generates heat. The solar wall collects heat including on sunny days when the sun isn't viewable. A control valve precludes the reverse flow of warm building air flowing reverse into the collector throughout the night. The solar wall is completely self-contained, beginning and halting without any need for human intervention.

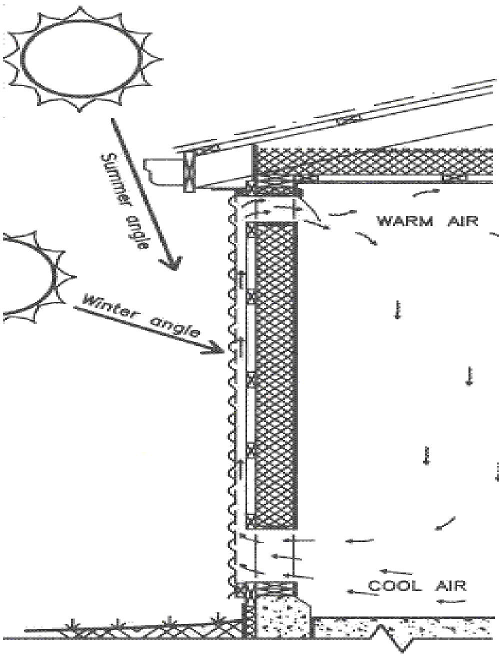

Fig 4. Passive solar wall

IV. Application of SAH

Because of their inherent simplicity and cost effectiveness, solar air heaters (SAHs) have been widely used for years. It's a type of heat exchanger that converts solar energy into thermal energy. Because the fluid does not freeze or boil in these systems, they have a benefit above other exchangers. Small heat conductivity, low thermal capacity, and low air density are all drawbacks of SAH. SAHs are used to cure and dry concrete and clay building materials. Seasoning of wood, space heating, and curing of industrial products are some of the other applications. SAH is an essential component between many available solar heating systems because of its minimal use of materials and low cost. Solar energy can be used to heat the fluids as well. It can be used for a variety of things, including the drying of vegetables, fruits, and meats, as well as the incubation of eggs and other industrial purposes.

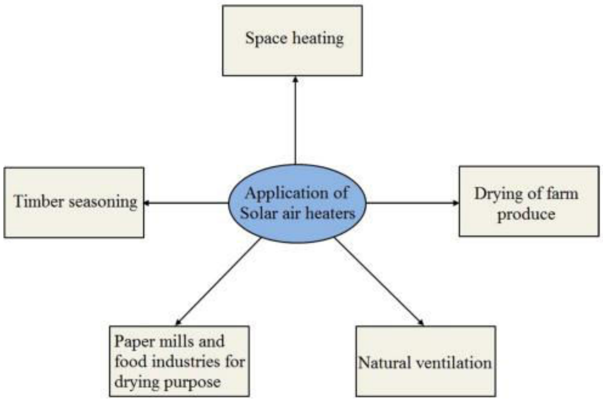

Fig 5. Application of Solar Air Heaters

When combined with photovoltaic (PV) systems, SAHs produce both thermal and electrical energy. PV/T collectors are what they're called [18]. Solar thermal systems also have the following benefits: they produce very little noise, they do not produce undesirable waste such as radioactive materials, and they are one of the cleanest technologies available. They are highly reliable systems with a lifespan of 20 to 30 years and low maintenance requirements. Solar systems have a number of drawbacks, including the need for innovative absorber design, non-uniform cooling, a longer payback period, lower efficiency, high production and installation costs, incompatibility with existing roof systems, and the need for more space for separate systems.

SAHs could also be used to heat spaces throughout the autumn and spring seasons, but their efficiencies are still lower than other systems. Numerous studies on heat transfer enhancement techniques for SAHs, such as attaching different shaped fns or baffles, surface treatment, flow direction change, and so on, have been published in the literature.

Solar energy storage is critical for the long-term success of solar energy use. The main issue is a lack of materials with adequate thermo-physical properties for storing solar energy as heat. These substances can be divided into two groups: those which store energy in the type of sensible heat, as well as those who change state or undertake a physical–chemical change at a specific temperature inside the pragmatic temperature range generated by solar heat collectors. Thermal heat storages for solar thermal applications include: (i) Sensible heat storage (SHS): sensible heat in solids.(ii) Latent heat storage (LHS): as latent heat of fusion in appropriate chemical compounds, the heat storage medium observations an uptick without changing phase.

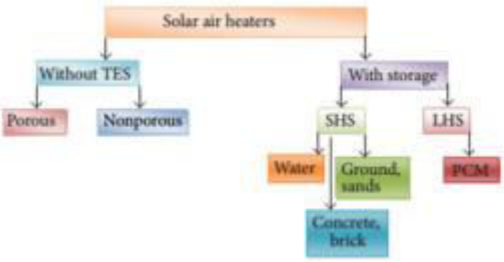

Fig 6. Classification of solar air heaters on the basis of TES

Really can these heat-storing substances enhance the thermal effectiveness of a SAH, but they can also prolong the timeframe of heating up to several hours. Aside from that, these materials' high heat-storage capacity is very helpful for solar thermal systems to operate in poor environmental temperature or at night.

V. PHASE CHANGE MATERIAL (PCM)

Across spinning dope as well as blending it into insulating foams or coatings, phase change materials (PCM) including paraffin can be implemented into textile materials, supplying a thermal controlling purpose. The physical state of PCM in the fabric changes from solid to liquid when the ambient temperature has reached the PCM melting point, actually results in heat absorption; heat to escape whenever the temperature rises the Phase change material freezing point.

Whenever a phase change material (PCM) shifts phase or state, it can absorb, store, and reveal huge quantities of latent heat more than a defined range of temperature. A PCM-containing fabric can function as a transient thermal barrier, regulating heat flux. PCMs absorb heat, causing a delay in microclimate temperature and, as an outcome, a significant reduction in the amount of sweat generated by the wearer's skin. Both contribute to improved wearing comfort and the prevention of heat stress.

PCMs have recently been explored for use in solar thermal storage and air conditioning in apartment complexes. The thermal insulation value of textiles used in roof coverings can be greatly improved by using PCM in coatings. The PCM can be recharged by the nighttime cooling effect after it has absorbed the excess heat during the day.

The use of phase change material (PCM) in the external walls has been thoroughly researched as a viable method for reducing energy consumption in buildings. PCMs are organic or inorganic materials (e.g., paraffin) with a low melting temperature and an elevated latent heat of fusion, and they are categorized as a capacitive type of insulation material.

PCMs are materials that can change their physical state over a very narrow temperature range. PCM stores, releases, or absorbs energy in the form of latent heat during phase transitions (i.e. when a phase change occurs). When PCMs change from a liquid to a solid state during the heating process, energy is stored (i.e. absorbed); when they change back to a liquid state, energy is released. These actions are usually transient, that is, they last until the PCM's latent heat is absorbed or released, at which point the temperature of the PCM remains unchanged.

Since phase change necessitates the transfer of an abnormally large amount of energy to start moving from one physical state to the other, PCM is an attractive candidate for latent heat storage. In layman's terms, PCMs are materials that absorb a lot of heat from their surroundings when it's hot and release it when it's cold. PCM's tendency to regulate heat flow through without changing temperature makes them a good supplier of heat storage for smart temperature control of textiles and clothing.

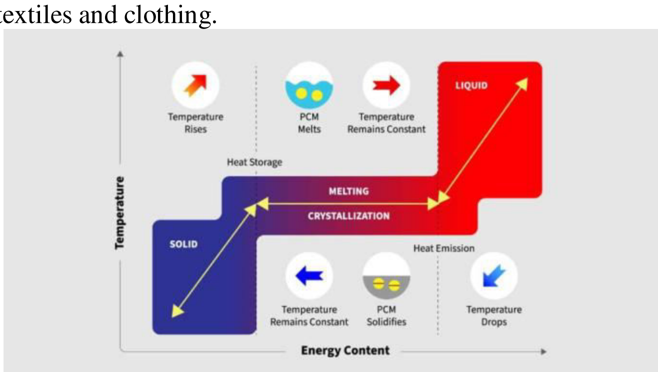

Fig 7. PCM's tendency to regulate heat flow

A. *Sensible Heat Capacity*

The internal temperature of a substance rises when it is heated without changing its phase. A glass of sun-heated water is a good example of this. When light shines on the water in the glass, it gains energy, the water molecules become more active, and the temperature of the water rises. This is referred to as "sensible heat." The ability of a material to absorb heat energy as its temperature rises is referred to as sensible heat capacity (warms up).

B. *Capacity of Latent Heat*

Whenever a glass of ice cubes is positioned in direct sunlight, the ice gradually melts. The ice melts when it attains the phase transition temperature of 0°C. When we take the temperature of the ice as it melts, we'll observe that it remained at 0°C until it's completely gone. This is because when a PCM, including ice, changes phase, the temperature is constant until the entire material has melted. Latent heat is the term for this.

As energy is absorbed, solid-liquid PCMs start behaving like sensible heat storage (SHS) materials, with their temperature increases. With exception of typical SHS substances, when PCMs attain their phase transition temperature (melting point), they absorb a large quantity of heat at a nearly constant temperature until the entire substance is melted. The PCM stiffens when the temperature all over a liquid substance falls, releasing the latent heat it has been storing. PCMs are come in a wide variety of temperature ranges, from 5 to 190 degrees Celsius.

VI. LITERATURE REVIEW

(Varshney, 2016) To increase the heat transfer rate and minimize losses while lowering energy consumption, the thermally performance of the solar air heaters must be improved. This article provides a brief description of solar air heaters with artificial roughness, which demonstrated significantly higher performance than traditional solar air warmers. In all of these research, efficiency improvement is primarily centered on raising the heat transfer coefficient in order to increase the heat transfer function and hence the effective heat transfer rate. Among several forms of artificial roughness, the chamfered type produces the greatest results, with a Nusselt number of 2.77 times higher (Nu=138.5) than the smooth duct for =14.5°, e/Dh=0.0278, p/e=5.41 and W/H=4.82. With the notion of double the heat transfer area, a dual pass solar air heater is more effective than a single passing solar air heater. The effect of geometric characteristics such as fin length, fin height, quantity of fins, selected coatings, thermal energy storage, and operational parameters such as flowrate on solar air heaters is also investigated in this study.

(Ghritlahre&Sahu, 2020) The main system for heating air in solar thermal systems is the solar air heater (SAH). It is of particular interest to academics because of its ease of fabrication and low cost. For the study of energy and exergy analysis, the first and second laws of thermodynamics are applied, respectively. The power analysis is critical for determining the effectiveness of a system, while the maximum exergy analysis is another important notion for examining the real behavior of a process that involves diverse energy loses and internal irreversibility. The exergy is a very significant tool for optimum development of solar air heaters for efficient usage of solar power. The purpose of this study is to examine previous work on energy and exergy analyses of different types of solar air heaters in order to identify research gaps for future studies.

(S. Singh et al., n.d.) One of them is the use of solar energy to turn it into thermal energy using a solar air heater. The thermodynamic efficiency of a solar air heater, on the other hand, is found to be extremely poor. As a result, the approach of employing artificial roughness on the heat exchange surface is considered an efficient way for improving thermal efficiency of the solar air heaters. The goal of this research is to evaluate several studies that have used various artificial roughness to improve the heat movement is essential and thermally efficiency of the solar air heaters.

(Tyagi et al., 2012) Solar energy is one of the most promising heat sources for satisfying energy demand while minimizing environmental impact. It can be used to provide process heat for dried agriculture, textiles, and marine products, as well as heat structures and regenerating dehumidifiers. As a result, it is critical for long-term development. Solar energy is a time-dependent and variable energy source. As a result of this, PCM-based thermal energy storage devices are becoming more popular for solar-energy-based heaters. Because latent heat is more effective than sensible heat storage, current research has concentrated on phase change materials (PCMs). In this paper, we have attempted to offer a comprehensive overview of the available solar air heaters for various applications as well as their performances.

(Alam& Kim, 2017) provides a comprehensive evaluation of the numerous heat transfer mechanisms utilized to boost the effectiveness of double-pass solar air heaters in the literature (SAHs). Increase the convective heat transfer, the heat exchange area, and reduce thermal losses to promote heat transmission from absorber surface to air. The design and development of double-pass SAHs has been influenced by these techniques, and the findings of various experimental experiments suggest that double-pass SAHs outperform single-pass SAHs. The literature on double-pass SAHs has been studied in order to better understand the various strategies utilized to increase performance. To understand better the performances behaviour of the various operational and system characteristics, they have been classified. A variety of strategies have been used to increase heat transfer, according to the literature. Extensive surfaces, corrugated substrates, artificial roughness, and packed beds are just a few of the qualities that can be used into the SAH design. Furthermore, it has been discovered that packing beds increase heat transfer rates while lowering environmental losses because insolation is absorbed in the depths of the packing material, resulting in a lower top layer temperatures and, as a result, a reductions in heat lost.

(Kumar et al., 2012) One of the most effective ways to improve the efficiency of solar air heater ducts is to add artificial roughness in the form of repeating ribs. The influence of various synthetic roughness geometry on heat transmission and frictional characteristics in solar air heater ducting has been investigated in a number of research. The goal of this work is to review a number of experiments in which producing synthetic roughness features have been employed to improve heat transfer coefficients while minimizing friction. An attempt is made to assess the thermal and hydraulic performances of rough surfaces solar air heater ducting using connections provided by various researchers for heat transfer coefficient and frictional factor. A large number of experimental and analysis research have been identified in the literature.

Singh & Bhagoria, 2021) The purpose of this paper is to provide a comprehensive overview of the literature on the use of CFD in the development of solar air heaters. Solar air heaters are one of the most basic items of equipment for converting solar energy into thermal energy. CFD is a modeling technology that employs powerful processor and applied mathematics to model fluids flow conditions for heating, masses, and mass transport predictions and full realization in diverse heat transfer and flow flow processes. The quality of the solutions derived from CFD simulations is generally satisfactory, demonstrating that CFD is a useful method for forecasting the performance and behavior of a solar air heater. The selection of a suitable turbulence model is one of the most difficult aspects of designing a solar air heater using a CFD technique.

(Jain et al., 2019) Solar air heaters (SAHs) are a popular and cost-effective equipment that absorbs solar energy and is used for space heating, dried farm goods, foodstuff, and leather, and seasoned wood, among other things. Artificial roughness applied to the absorber plate is an effective way to improve heat transmission from of the heat transfer surface to the air passing through the SAH duct. In terms of cooled turbines and engine components, researchers have been particularly interested in the use of friction factor. This method works well for improving thermal performance in a micro-channel heating/cooling systems. The current research presents a comprehensive overview of the numerous types of V-shaped roughness geometry utilized in SAHs for increasing performance, including empirical, analytical, numerical, and computational fluid dynamics (CFD) techniques. 124 research publications have been cited in this paper, all of which provide a complete, comprehensive, and comparative investigation demonstrating the impacts of multiple geometry factors and distinct V-shaped roughness patterns on SAH performances. This page also includes information on the heat transmission and friction factor association produced by researchers.

VII. CONCLUSION

Solar air heaters (SAHs) are devices in which solar energy is collected by a receiving point and the heat conduction is retrieved by air moving over it. SAH is the most cost-effective method of converting solar energy and is utilized in a variety of applications including as room heaters, crop drying, and other industrial purposes. The purpose of this paper is to provide an overview of SAH and its classifications

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