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Solar Air Heater Duct with Wavy Delta Winglets: Correlation Development and Parametric Optimization: A Review

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Abstract:- *Solar air heater is the most popular device in the space heating and industrial processes applications. But solar air heater has a lower heat-transfer coefficient between the absorber plate and the air stream, which results in a lower thermal efficiency of the heater. The solar air heaters efficiency can be affected by various parameters such as collector length, number of channels, depth of channels, type of absorber plate, number and material of glass covers, air inlet temperature and air velocity. In this work, a review of the available literature on solar air heater, for the performance improvement is presented; the review is made to allow a discussion based on fins, baffles & obstacles, proposed by various researchers. Considering the parameters, this is enhancing the performance of a solar air heater.*

Keywords: Solar Collectors, Obstacles, Fins, Heat Loss, Baffles, Thermal Efficiency.

INTRODUCTION

The fast growth of population & industrialization are the basic reasons behind increasing energy demand. Conventional energy sources are used to meet this demand. Developing countries are heavily dependent on fossil fuels, for their energy needs. This causes the depletion of fossil fuel resources and the degradation of the environment. Solar air heater is a device, which converts solar radiation into heat energy. This device is simple and can be constructed less expensively. Solar air heater made up of a wooden, galvanized iron sheet, or FRP/GRP material. Absorber plate is coated with black paint to absorb maximum solar radiation and clear glass cover provided to the top to allow maximum solar radiation inside, inclination provided to the solar air heater for the maximum solar radiation received during the day period. Insulation of glass wool, thermocol, wooden plates, asbestos, etc has been provided to the outer wall of sides to reduce the heat losses in the atmosphere. Solar air heater directly exposed to the sunlight. Figure 1, a single flow single-pass system, the airflow enters through the channel and solar radiation absorbed by the absorber plate. The absorbed heat transferred to the air as it flows along the channel and its temperature going to be increased. This hot air can be used in several applications such as drying agricultural products, space heating, and air conditioning, water heating, and industrial process heating. There are so many advantages of solar air heating systems. Firstly, they are simple to maintain and design. After the set-up cost, a solar air heater system has no fuel expenditure. There are less leakage and corrosion when compared to the systems that use the liquid. It is also an eco-friendly system which has zero greenhouse gas emissions.

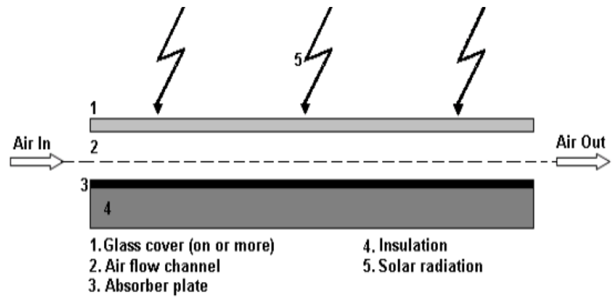

Figure 1 A schematic view of a single flow single pass

The use of renewable energy sources may be an alternative to fossil fuels, which also saves the environment. Therefore, there is a great need to explore renewable energy sources and to develop renewable energy, based technologies to meet our energy demand in the present context. Solar energy is the one most abundant renewable energy source and emits energy at a rate of 3.8x1023kW of which, approximately 1.8x 1014kW is intercepted by the earth [1]. There are lots of review articles, already published in the area of air heaters. This review aims to merge the efforts of the researchers working on solar air heater and find the pathways to present it by means of robust applications to use, and thus, to enhance the performance for consideration in the design and development [2]. The most important use of solar thermal technology & its application is drying air, which is further utilized for space heating, especially in winter's & for all drying processes, wherever applicable[3]. The easiest & the most able way to make use of solar energy are, to transfer the thermal energy for drying applications, through the use of solar collectors. Solar air heater, because of simple design is cheap & most commonly used [4]. The thermal performance ability of solar collectors depends on- material & shape & layout of the collectors. The raise in performance improvement could be possible with these parameters. The modification helps to improve the heat transfer coefficient, in-between the absorber plate & the air, which includes the use of absorbers with corrugated & matrix type, with packed bed, baffles & fins, etc.

HISTORY OF SOLAR AIR HEATING

Solar heating systems have been in use for many years. Solar heat stored in iron was used in 1877 as reported by Daniels and Duffie [5]. The air blowing over the heated iron was then used to heat a home. The first accredited

SAH was designed and produced by E. Morse (an American) in 1881. The design deals with a simple wall-hung wooden framed cabinet for a blackened metallic sheet covered with a transparent glass. It works purely on convection; the hot air would be emitted through a solar absorber made of steel within the cabinet of the system. The system got a little attention, although variations were developed but were not known exactly [6]. Several solar-heated homes have been constructed and operated successfully over the past years. Between, 1946–1949, two residences in Massachusetts have explored a new level of solar air heating by using chemical compounds that absorb and release heat as needed by changing its state from a solid to a liquid one. At present, this technology is referred to as phase change materials (PCMs) and has numerous applications in industries, worldwide. Since that time, three more houses were built at MIT and research was continued up to 1978. The components used to be simple and reliable in operation and relatively easy to install by the homeowner. In the past few years, many manufacturers of these components apparently recognized the trend to install toward do-itself solar heating system on its own, especially for building or space heating [7-8] Show that Cabot (1938) marked the beginning of modern research in solar heating at the Massachusetts Institute of Technology (MIT).

VARIOUS DESIGNS OF SOLAR AIR HEATERS

The air type solar collectors are commonly used for agriculture drying [9]; timber seasoning [10] and space heating applications [11], their basic advantages of these systems are low sensitivity to leakage as well as no need for an additional heat exchanger for drying and space heating applications. However, because of the low heat capacity of the air and low convection 'h' between the absorber and the air, a large heat transfer area, and higher flow rates are needed. The air has been used as the working fluid in solar heating systems since World War II. Although demonstrated in fewer buildings than liquid systems, the air systems have several advantages that can lead to their use in smaller installations in single and multifamily residences. In addition, the air systems are well suited to crop drying and air preheating in a certain process. There have been numerous types of solar air heating collectors designed, previously. Among them, the focusing type employing lenses or mirrors to concentrate the solar energy into a small, high-temperature area has been built in a variety of forms. Considerably, with greater interest from the standpoint of economic practicability, there are several types of FPC in which a fluid is heated by contact with surfaces which in turn heated by solar radiation passing through one or more flat glass surfaces. SAH involves solar heat collector, sloping, FP type, in which ordinary single-strength window glass is employed both as a heat exchange surface and as an 'insulating medium', to reduce the escape of heat to the atmosphere. The purpose of the collector unit is the heating of the air by passing it between overlapped glass plates and delivering heated air to a dwelling, to a solar dryer, or to a heat-storage unit [12].

Whillier [13] had carried out performance analysis of a conventional SAH concerned primarily with black-painted collectors for some different objectives such as; heat-transfer analysis, to predict useful heat collection, to demonstrate significant improvement by use of the screens, and to compare the performance of glass and Tedlar covered SAHs. Khanna [14] had been investigated an SHS integrated with a heat exchanger and storage coupled to two water heaters. The heat transferred from water to air in the heat exchanger and the temperature of exhaust was estimated by considering various parameters. The data obtained was helpful to design a shell-and-tube type heat exchanger which can be used for drying a particular material through the system.

Loveday [15] had derived expressions for efficiency and loss factors of a coverless SAC. In the geometry treated, the airflow was beneath a flat absorber with a steady-state heat transfer. The expressions were validated by outdoor measurements from a full-scale tile roof used as a collector and by indoor measurements from tile and metal roof sections. It was shown that the system's performance as the collector may be described by a 'fin and tube' model. Results were found to be useful for design and may be used in the computation of the thermal performance of the solar-assisted buildings.

Choudhary et al. [16] had been presented a detailed theoretical parametric analysis of a one-pass corrugated bare-plate SAH. Obtained results were found useful for the designer to calculate performance and optimize the design and also to improve efficiency without increasing the cost. A good agreement of theory with experimental observations confirmed that the optimization procedure discussed which can be used to obtain fairly accurate optimum performance and optimum design parameters of the SAHs for any amount of the air flowing through the heater channel.

EFFECT'S OF ARTIFICIAL ROUGHNESS

Artificial roughness is extensively introduced for the enrichment of forced convection heat transfer; it requires a turbulent flow on the heat transfer fade, so that, it is used to improve heat transfer & hence, improving thermo hydraulic performance of SAH. As forced convection heat transfer requires energy coming from a fan & or a blower, turbulence is taking place close to the heat transfer plane, to decrease the power requirement. It can be achieved, while maintaining the Element height small, as compared to heater duct dimensions. To describe roughness, dimensionless geometrical parameter is used [17], as the relative roughness of pitch, & height, &Angle of attack, & Aspect ratio & the shape of the roughness element.

Gupta & Kaushik [18] performed an analysis in artificially roughened SAH, & integrated with extended metal mesh, on the absorber plate compared with conventional heater. The study is exercised to evaluate performance in way of ratios of energy expansion, useful energy expansion & energy augmentation at different Reynolds numbers (Re), & roughness parameters on prolonged metal mesh unevenness geometry. The expansion ratio is improved, by using extended metal mesh type roughened geometries in the duct. The EXAR reduces with Re, & maybe less than unity & may be negative when energy of the pump work required, & it becomes larger than the energy of the heat energy collected in roughened heater, but it is greater than unity for the larger flow c area/s of the heater, along with low Re values & higher solar radiation intensity.

Peng et al. [19] analyzed the thermal efficiency of the novel SAH of pin-fin incorporated absorber. The result predicts that heat transfer coefficients for pin-fin array collectors & flat-plate collector is performed, at an airflow rate of 19 m3/h. The outcomes showed that the heat transfer coefficient of pin-fins SAH is 3 times that of FPSAH. Also, the middling thermal efficiency reached 0.5%–0.74%. Correlation equation is used for getting the highest thermal efficiency, as a function of dimensionless pin-fin span & dimensionless pin-fin height. Also, the correlation equation was exercised, to calculate the heat transfer coefficient.

Momin et al. [20] made a survey on the V-shaped rib, to examine the effect of relative roughness &height & angle of attack. This study is confined for fixed relative roughness pitch & height, about 10&0.034, along with a Reynolds number of range 2500 to 18000. The display of ribs is illustrated in Figure 2. The results predict the rate of enhancement in the friction coefficient was higher than that of the rate of increase of the Nusselt number, due to the rise of the Reynolds number. Use of V-shaped ribs achieves an improvement in Nusselt number, from 1.14 & 2.30 times over inclined ribs & smooth plate.

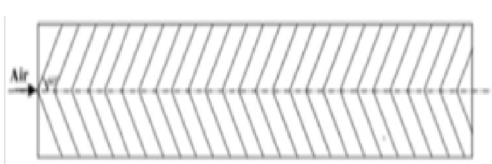

Figure 2 Type & Orientation of the Roughness Element

EFFECT OF WINGS AND WINGLET TWISTED TAPE

Smith Eiamsaard et al. [21] and Eiamsaard et al. [22] investigated the effect of delta winglet twisted tape inserts on heat transfer and pressure drop characteristics. The investigation was made for straight and oblique delta winglet as shown in Fig. 3 along with twin delta-winged twisted tape inserts as shown in fig. 4. They analyzed twisted tapes for different twist ratios and depth of wing cut ratios. From the results, it was concluded that oblique delta-winglet is more efficient than a straight delta winglet. Over the range of Re studied, TPF for oblique delta winglet twisted tape and straight delta winglet wisted tape was found to be 0.92–1.24 and 0.88–1.21 respectively. The twin delta-winged twisted tape wings were cut in three different positions: up, down and opposite [22]. Wings were inclined at an angle of 150 with the tape surface. The effect was examined for three different wingtip angles of 200, 400 and 600. The result revealed that the upside position performs well compared to down and opposite side wings; heat transfer rate increases with wingtip angle; twin tape wing up with 20_ wing tip angle gives the highest TPF of 1.26. Instead of using twisted tape inserts, Deshmukh and Vedula [23] used a curved delta type vortex generator (Fig. 5) to analyze the heat transfer and friction factor characteristics of flow through a circular tube. The insert was constructed with a central rod on which curved delta wings were attached at specific locations.

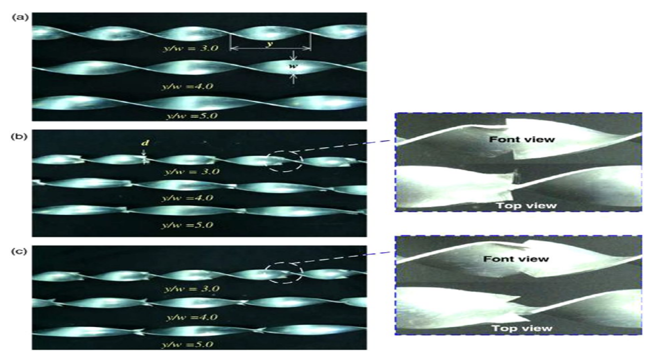

Figure 3 Oblique delta winglet

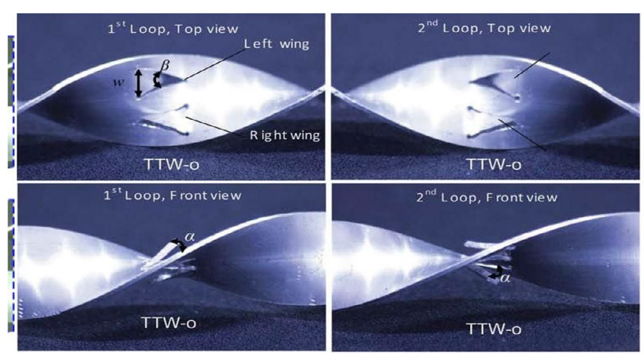

Figure 4 Twisted tape with twin delta wings

Behfard and Sohankar [24] conducted a numerical study of the delta-winglet vortex generator used in a rectangular duct. They found a TPF of 1.49. Augmentation of heat transfer by using wire-rod bundles was investigated by Nanan et al. [25]. Analysis was done for 4, 6 and 8 wire bundles with three different pitch ratios. The heat transfer rate increased compared to the plain tube. But TPF was less than one in most of the combinations. The combined effect of the twisted tape and vortex generator was experimentally investigated by Promvonge et al. [26]. Experiments were conducted in a square duct with simple, two V winglets and four V winglets with a fixed angle of attack of 300. The highest TPF of 1.62 was obtained which was 17% more than that of twisted tape.

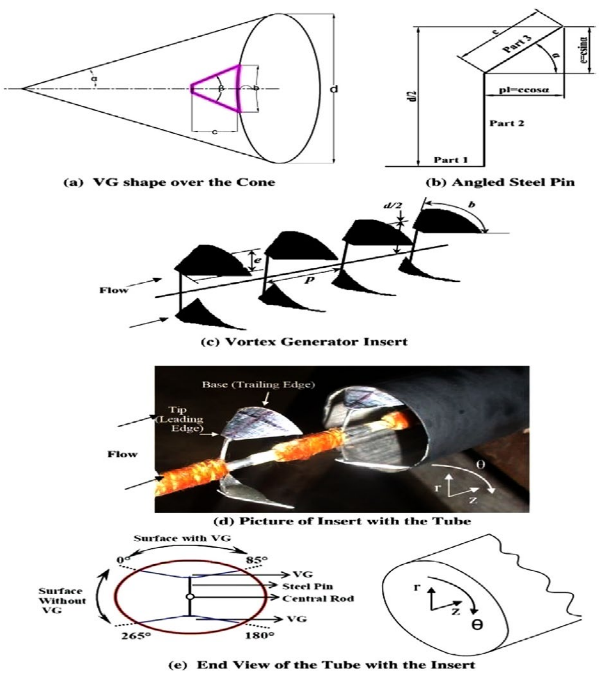

Figure 5 Geometrical details of delta wing vortex generator

Arul prakasa jothi et al. [27] investigated the effect of staggered and non-staggered conical strip inserts in a circular tube under laminar flow condition. The conical strip of forward and backward direction was used as turbulators which led to an enhanced heat transfer coefficient. Numerical simulation was carried out by Zheng et al. [28] to investigate the effect of the vortex rod in a heat exchanger tube. Their results revealed that the vortex rod inclination angle, diameter ratio, and Re affects heat transfer and friction factor considerably. Also by using Artificial Neural Network, they concluded that the vortex rod with diameter ratio 0.058 and inclination angle 57.05 at Re = 426.767 gives the best TPF.

CONCLUSION

From the present review, it can be concluded that the heat transfer enhancement occurs in all cases due to a reduction in the flow cross-section area, an increase in turbulence intensity and an increase in tangential flow established by various types of inserts. Geometrical parameters of inserts like width, length, twist ratio, etc. affect the heat transfer enhancement considerably. The regularly spaced twisted tape does not generate turbulence in the non-twisted tape area. Therefore, it is better to use full length twisted tape instead of regularly spaced twisted tape. In large Prandtl number flow, roughness performs better than the twisted tape and the maximum heat transfer occurs due to roughness when the roughness height is three times the viscous sub-layer thickness. The artificially corrugated rough surface can be developed to significantly improve the heat transfer characteristics by breaking and destabilizing the thermal boundary layer on the surface. Passive techniques are widely used in various industries for their cost-saving, low maintenance requirements and easy setup.

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