Latest Evolutions in Flat Plate Solar Collectors Technology

Munish Kainth[1], Vivek Kumar Sharma[2]

[1,2] Mechanical Engineering Department, Universal Institute of Engineering & Technology, Lalru, Punjab (India)

[1]kmunishk@gmail.com, [2]vivek3052@yahoo.com,

Abstract- The main objective of this paper is to make more and more people acquainted with developments in the Flat-Plate Solar Collector technology in the last 10 years. We all know that the conventional sources of energy create a lot of problems for the environment and also for people's pockets. So this has compelled some of the excellent minds on earth to search for the replacement of these conventional sources of energy. Solar energy is the best alternative as it is available to us in huge amounts. The Flat-Plate Solar Collector is basically a device that helps us harness the solar energy to do useful work. Though a huge amount of energy is available to us but only a fraction of this energy is converted to useful work. Over the years scientists have performed a lot of experiments to improve the working efficiency of the Flat-Plate Solar Collector and they have succeeded also. This paper is will give you a review as to what all has been done on the Flat-plate solar collectors.

Keywords: Solar Panel, collector, flat-plate, fraction.

I. INTRODUCTION

A solar thermal collector collects heat by absorbing sunlight. A collector is a device for capturing solar radiation. Solar radiation is energy in the form of electromagnetic radiation from the infrared (long) to the ultraviolet (short) wavelengths. The quantity of solar energy striking the Earth's surface averages about 1,000 watts per square meter under clear skies, depending upon weather conditions, location and orientation.

Flat-plate collectors are in wide use for domestic household hot-water heating and for space heating, where the demand temperature is low. Flat-plate collectors, developed by Hottel and Whillier in the 1950s, are the most common type. They consist of (a) a dark flat-plate absorber, (b) a transparent cover that reduces heat losses, (c) a heat-transport fluid (air, antifreeze or water) to remove heat from the absorber, and (d) a heat insulating backing.

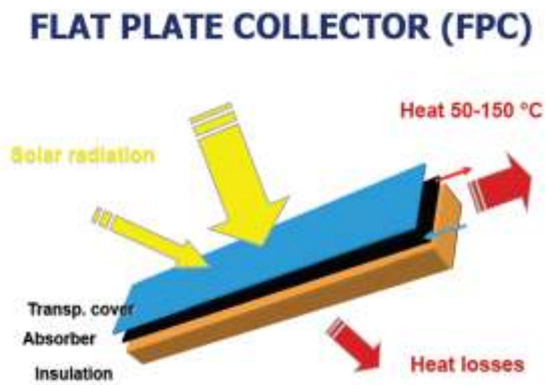

Fig 1: Flat Plate Collector

The absorber consists of a thin absorber sheet (of thermally stable polymers, aluminum, steel or copper, to which a matte black or selective coating is applied) often backed by a grid or coil of fluid tubing placed in an insulated casing with a glass or polycarbonate cover. In an air-based collector the circulating fluid is air, whereas in a liquid-based collector it is usuallywater.

Flat-plate collectors heat the circulating fluid to a temperature considerably less than that of the boiling point of water and are best suited to applications where the demand temperature is 30-70°C (86-158°F) and/or for applications that require heat during the winter months.

Air-based collectors are typically used for heating buildings and drying crops. Liquid-based may be glazed or unglazed. Glazed liquid collectors are the commonest type of solar collector for providing domestic and commercial water and for heating indoor swimming pools. Unglazed collectors are most often used for heating outdoor pools. A special type of unglazed collector called a perforated plate collector is used to preheat ventilation air for commercial buildings or, in some cases, for drying crops [1].

Flat collectors can be mounted in a variety of ways, depending on the type of building, application, and size of collector. Options include mounting on a roof, in the roof itself, or free-standing. Now the developments in this field are listed below.

II. LITERATURE REVIEW

In this section the various developments in this field in last 10 years are listed with their results and conclusions.

Dupeyrat et al., 2011

The focus of the first part of this paper is on the development and testing of a flat-plate PVT collector. Through broad numerical and experimental investigations on PV technologies (PV cell, module construction and materials) several prototypes of a covered flat-plate PVT collector were manufactured. In figure, the designs of two prototype PVT collectors are presented.

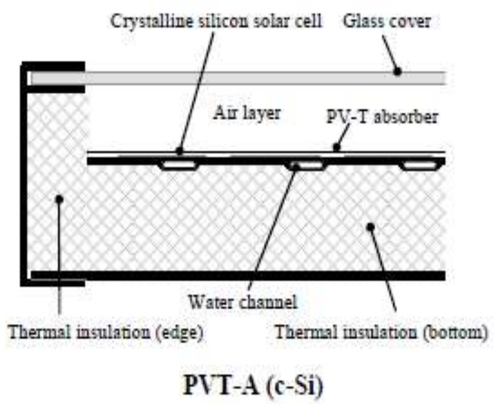

Fig 2: Cross sections of two covered flat-plate PVT water collectors.(PVT-A) with laminated c-Si solar cells [1]

For the first collector (PVT-A), the PVT absorber was manufactured using an improved technique for the lamination of single-crystalline silicon solar cells on the top of an optimized flat heat exchanger. This PVT absorber was then encased in the frame of a solar collector. At the front, between the absorber plate and the high transmission glass cover ($\tau > 0.93$), a static air layer with a thickness of 20 mm was set up to ensure good thermal insulation. The aperture area is A_{col}=1.01 m².

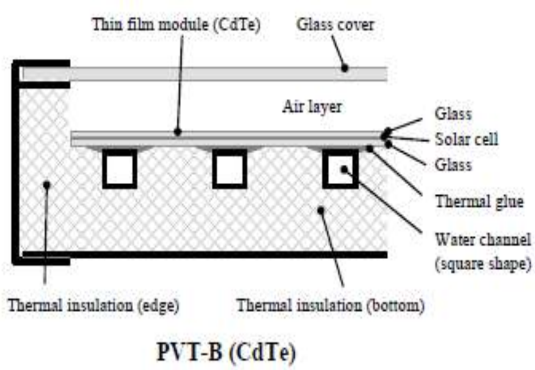

Fig 3: (PVT-B) with CdTe thin film solar cells [1]

For the second collector (PVT-B), the PVT absorber was assembled connecting square copper channels mechanically and thermally on the back of a conventional thin film module (CdTe). CdTe modules have a lower efficiency than sc-Si modules, but their temperature dependency is much lower as well. The relative temperature coefficient of CdTe thin film is around -0.20 %/K, compared to -0.45 %/K for silicon cells. This PVT absorber was also encased in the frame of a solar collector. At the front, the static air layer has a thickness of 45 mm. The aperture area of the collector is A_{col}=1.55 m².[1]

Wenfeng Gao, Wensian Lin, Tao Liu, Chaofeng Xia, 2006

In the following research paper experimental analysis of the cross corrugated absorber plate is studied experimentally and analytically. The cross corrugated plate is the wave like shaped absorbing plate and also a wave like bottom plate, which are crosswise positioned to form the airflow channel. 2 types of configuration were settled for this study. First the absorber plate was along the flow direction and the bottom plate was perpendicular to the airflow direction. The main aim of using the bottom plate was to create more and more turbulence and also to increase the heat transfer rate. Now the thermal performances of these 2 types with a conventional flat-plate solar collector were compared.

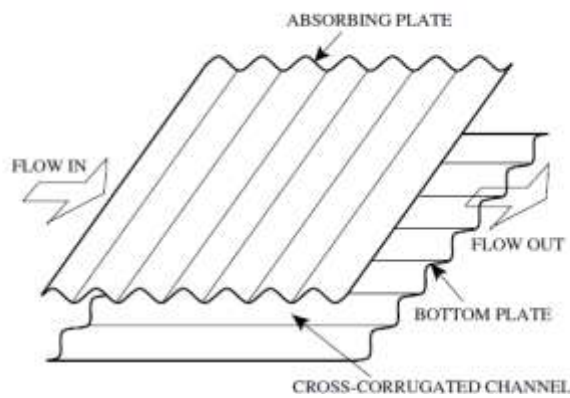

Fig 4: schematic description of corrugated plates of type 1 [2]

First the solutions are obtained according to typical configurations and operating conditions for all the 3 types of the solar collectors. The effect of specific coatings was also studied.

After the experimental and the analytical studies the final result was that-

- The thermal performance of the type 2 heaters is slightly superior than the type 1 heater but both these corrugated show a significant increase in the efficiency shown by the conventional collector. Numerically the efficiencies were 58.9%, 60.8% and 49.7%
- The use of selective coatings on the absorber plate of all these collectors enhanced there efficiency

individually. It was also concluded that the selective coatings should not be applied to the bottom plate and glass covers.[2]

Zhang Zhiqiang, Zuo Ran,LI Ping and Suwenjia, 2009

Transparent honeycomb structure with thin-walled glass tube of a small aspect ratio (*L/D*<3) as the honeycomb unit is designed and applied to a flat-plate solar air collector. Experiments are performed for solar collectors with six different honeycomb sizes. The emphasis is to study the effects of diameter and aspect ratio of the honeycomb unit on the transmittance and efficiency of the solar collector. The use of the transparent honeycomb as the collector cover plate reduces heat loss and increase the thermal efficiency.

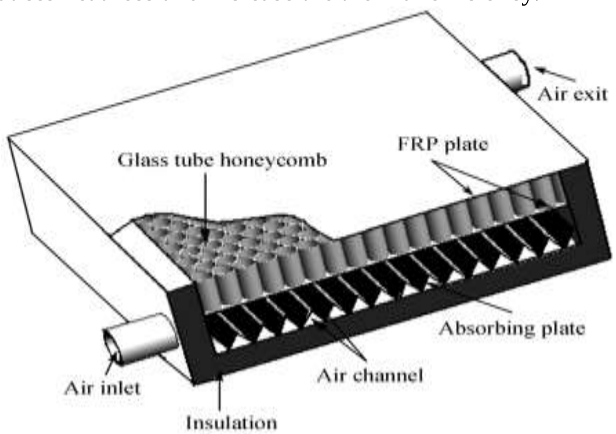

Fig. 5: Honeycomb Structure

The transparent honeycomb plate is made of the thin-walled glass tubes which come from the scraps of the vacuum tube solar collector and the double-layer of Fiberglass Reinforce Plastic (FRP) material as supporting plates. Three different diameters and five different heights are used to construct five different honeycomb structures for the solar collector.

And the results were.

1) The air temperature of the collector is mainly affected by the honeycomb aspect ratio and the material's transmittance, but not the actual honeycomb size. For the same diameter but different aspect ratios, the collector of smaller aspect ratio has higher exit temperature.

For the same aspect ratio but different diameters, the temperature differences between collectors are small.

2) The collector of smallest aspect ratio yields the highest average temperature, and the collector of double-layer FRP plate without honeycomb has the lowest average temperature. The highest average temperature difference is about 12^{o}.

3) A simple theoretical formula about honeycomb and transmittance is derived, which is only a function of aspect ratio, material's optical transmittance, and the solar incident angle of the honeycombs. The theoretical results well agree with the experimental data.[3]

A.Hachemi 1999

The thermal heat performance of a solar air collector depends strongly on the thermal heat loss and the efficiency factor .In order to increase these performances, it is necessary to use a solar air collector which is well insulated and where the flow is turbulent. This can be achieved by a properly finned system. In the present study we are interested by the computation of these heat transfer and thermal heat loss coefficients and the efficiency factor of the solar collectors with finned system and with selective and nonselective absorber plates.

In spite of the use of the selective absorber, the experimental results show that there is no great enhancement of the thermal performance when the nonselective absorber plate is replaced by a selective absorber plate. The fin system placed in the collector duct creates a fully turbulent flow, at relatively low mass flow rate, which develops a high heat transfer between the heated plate (absorber) and the fluid (air). This results in a high heat transfer coefficient, a low heat loss coefficient and a high efficiency factor. The difference between the selective and the nonselective characteristics is relatively low and in order to avoid the use of selective absorber we can use the nonselective absorber also.[4]

B. Donatien Njomo, Michel Daugenet, 2003

Sensitivity analysis is a mathematical tool, first developed for optimization methods, which aims to characterize a system response through the variations of its output parameters following modifications imposed on the input parameters of the system. Sensitivity analysis is used for thermal design studies to understand the relationships and study the impact of input parameters on different simulation outputs. Such an analysis is very difficult when the thermal model under consideration is complex or the number of input parameters is high. In this work only the most significant input parameters such as the incident irradiation, the inlet fluid temperature, the air mass flow rate, the depth of the fluid channel, the number and nature of transparent covers, the selectivity of the absorbers were investigated. The main objective of this study is to demonstrate that the heat transfer model developed is robust enough to be used for thermal design studies of most known flat plate solar air heaters, and even of flat plate solar water collectors and linear solar concentrators.[5]

G. Alverez, J. Arse, J. Lira, 2004

G. Alverez with his colleagues developed and tested the efficiency of a single-glass solar air collector with the absorbing plate made up of recyclable aluminum cans. The absorbing plate consisted of 8 circular cross-sectional air flow channels of 128 Recyclable aluminum cans whereas each channel consisted of 16 recyclable cans coated with a black paint of 0,907 absorptance and 0.097. The collector geometry considered was 2m in length, 0.5m in width and 0.065 in diameter. Now the efficiency of the RAC was compared with some of the other collectors as well and the results were that its efficiency was greater than the single air flow, double air flow and Double air pass solar collectors. In the graph below is between the thermal efficiency of the RAC and some previously constructed solar air heaters [6].

Turhan Koyuncu, 2005

Different sources of heat are used for crop drying. A Flat plate solar collector is 1 of them. He designed constructed and analyzed for their performance.

- Model 1-Single Plastic Glazing ,black painted hardboard absorber and front pass
- Model 2-Single Plastic Glazing ,black painted flat plate absorber and front pass
- Model 3-Single Plastic Glazing ,black painted zigzag absorber and front pass
- Model 4-Single Plastic Glazing ,black painted flat plate absorber and back pass
- Model 5-Single Plastic Glazing ,black painted zigzag absorber and back pass
- Model 6-Double Plastic Glazing ,black painted flat plate absorber and back pass

All the solar collectors were mounted in the southern direction and placed at a predefined inclination angle. All the models were tested in the same weather conditions and with the same air flow. The experiments were done in the north of turkey latitude=41.21 longitude=36.15 altitude=4m with an airflow of 65kg/(hm^2).

After the experiments were performed it was investigated that the performance of the Model 1, Model 2, Model 3, Model 4, Model 5 and Model 6 were 42.11, 45.88, 44.23, 39.76, 39.05 and 36.04% respectively. This clearly shows that the performance of the most efficient collector is 9% more than the least efficient.[7]

A.A.El-Sebaii,S.Aboul Enien,M.R.I.Ramadan,S.M.Shalaby,B.M.Moharram ,2010

Under this the double pass-finned plate solar air heater was investigated theoretically and experimentally. Comparisons between the measured outlet temperature of flowing air, temperature of the absorber plate and output power of the double-pass finned and v-corrugated plate solar air heater were also presented .The effect of mass flow rates of air on pressure drop, thermal and thermo hydraulic efficiencies of the double pass-finned and v-corrugated plate solar air heaters were also investigated.

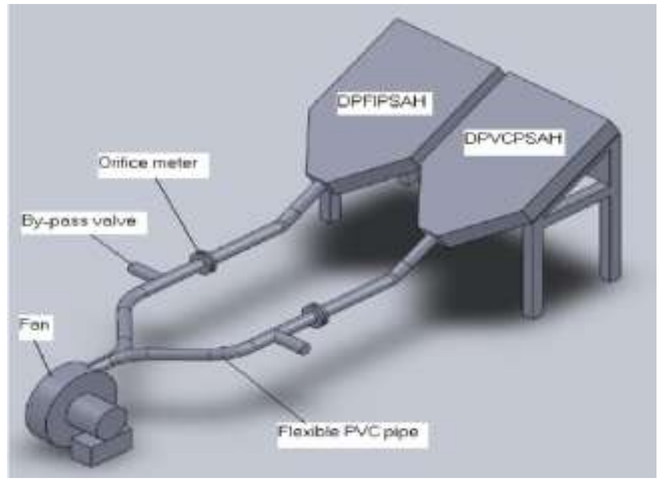

Fig 6: The schematic diagram of the experimental setup is shown above [8]

The result showed that the double pass v-corrugated plate solar air heater is 9.3-11.9% more efficient as compared to double pass-finned plate solar air heater. The optimum values of the thermo hydraulic efficiencies of the double pass v-corrugated plate and double pass-finned plate solar air heaters are obtained when the mass flow rates of the flowing air equal 0.0125 and 0.0225 kg/s respectively [8].

III. CONCLUSION

In the above literature review section some of the developments in the flat Plate Solar collector are discussed. The basic idea of all the research is to increase the efficiency of the Flat-Plate Solar Collector and also reducing the heat losses occurring in the particular device.

This is achieved by making improvisations and innovations in the different parts of the air collector. Weather it may be done by the use of selective coatings [6], by modifying the path of the air flow so the heat transfer is proper [8], by using fins to increases the heat transfer rate [8].

Use of the corrugated sheet [6] instead of the flat plate absorber also increased its thermal efficiency and reduced the losses.

The use of Honeycomb structure [3] considerably reduced the infrared losses. Not only have this efforts also been made to improvise economically by the use of recyclable materials like recyclable aluminium cans.

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