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A review on advancements in solar flat plate collectors

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Abstract : Solar collector is an important technology for the effective utilisation of solar energy that the earth is blessed with. Flat plate solar collectors present a simple and easy to maintain design and thus are widely used for low and medium temperature applications. But being less efficient than alternatives, justifying the initial investment of flat plate solar collectors becomes difficult in the long run. This paper presents the efforts of researchers in the past some years to improve the efficiency of flat plate solar collectors through the improvement and optimization of the existing design. This paper will be beneficial for exploring the range of research avenues in the field of optimization and efficiency improvement of flat plate solar collectors.

***IndexTerms* – Solar energy,Solar collector,efficiency,Design.**

I. INTRODUCTION

A Flat Plate Collector is a heat exchanger that converts the radiant solar energy from the sun into heat energy using the well known greenhouse effect. It collects, or captures, solar energy and uses that energy to heat water in the home for bathing, washing and heating, and can even be used to heat outdoor swimming pools and hot tubs. For most residential and small commercial hot water applications, the *solar flat plate collector* tends to be more cost effective due to their simple design, low cost, and relatively easier installation compared to other forms of hot water heating systems. Also, solar flat plate collectors are more than capable of delivering the necessary quantity of hot water at the required temperature.

II. CONSTRUCTION OF FLAT PLATE COLLECTOR

A solar flat plate collector typically consists of a large heat absorbing plate, usually a large sheet of copper or aluminium as they are both good conductors of heat, which is painted or chemically etched black to absorb as much solar radiation as possible for maximum efficiency. This blackened heat absorbing surface has several parallel copper pipes or tubes called risers, running length ways across the plate which contain the heat transfer fluid, typically water. These copper pipes are bonded, soldered or brazed directly to the absorber plate to ensure maximum surface contact and heat transfer. Sunlight heats the absorbing surface which increases in temperature. As the plate gets hotter this heat is conducted through the risers and absorbed by the fluid flowing inside the copper pipes which is then used by the household. The pipes and absorber plate are enclosed in an insulated metal or wooden box with a sheet of glazing material, either glass or plastic on the front to protect the enclosed absorber plate and create an insulating air space. This glazing material does not absorb the suns thermal energy to any significant extent and therefore most of the incoming radiation is received by the blackened absorber. The air gap between the plate and glazing material traps this heat preventing it from escaping back into the atmosphere. As the absorber plate warms up, it transfers heat to the fluid within the collector but it also loses heat to its surroundings. To minimize this loss of heat, the bottom and sides of a flat plate collector are insulated with high temperature rigid foam or aluminium foil insulation as shown in fig 1. Flat plate collectors can heat the fluid inside using either direct or indirect sunlight from a wide range of different angles. They also function in diffused light, which is dominant on cloudy days as it is the surrounding heat that is being absorbed and not the light, unlike photovoltaic cells. How hot the circulating water gets will depend mostly on the time of the year, how clear the skies are and how slowly the water flows through the collectors pipes.

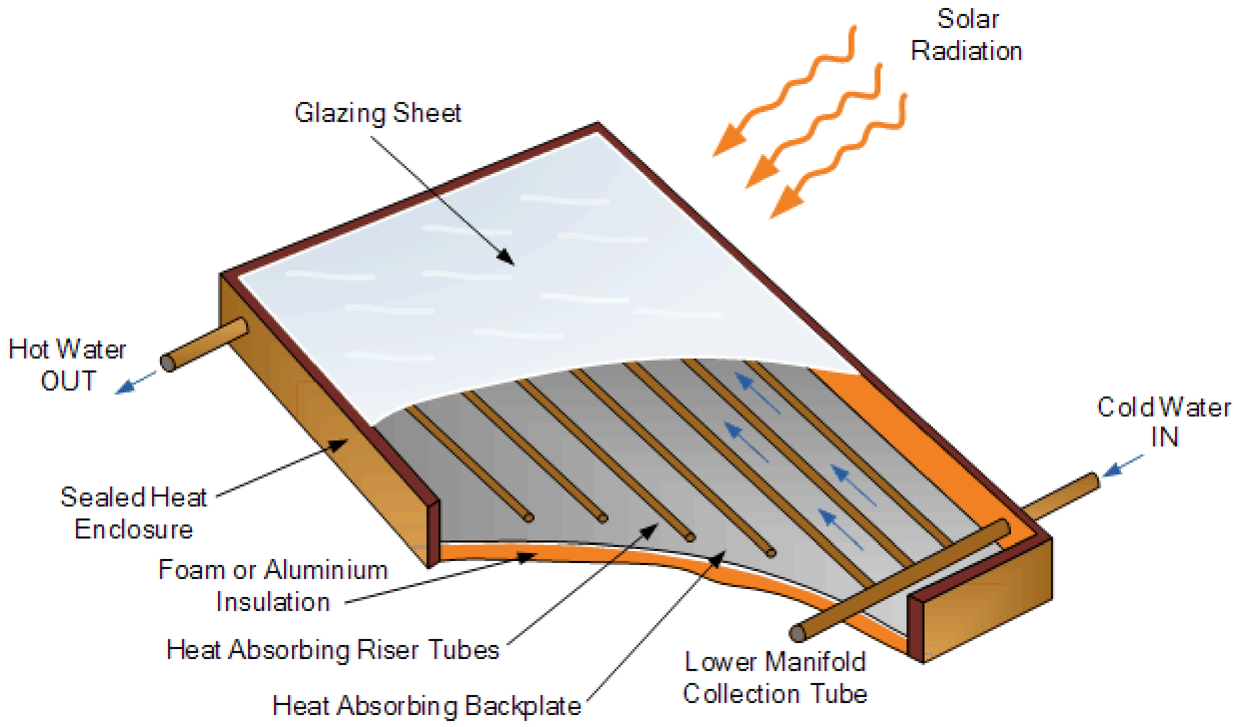


Fig. 1

Flat plate collectors can heat the fluid inside using either direct or indirect sunlight from a wide range of different angles. They also function in diffused light, which is dominant on cloudy days as it is the surrounding heat that is being absorbed and not the light, unlike photovoltaic cells. How hot the circulating water gets will depend mostly on the time of the year, how clear the skies are and how slowly the water flows through the collectors pipes.

III. Types of collectors.

1. **Flat Plate Collectors**

FPC'sare the most simple and common types of solar collectors that anyone can see in their areas. These are basically metal boxes with a dark-coloured absorber plate and have a transparent glazing cover on the top.
Such plates are generally fabricated from a metal, such as copper or aluminium, which is a good conductor.
For better absorption and retaining of heat, these absorber plates are sometimes painted with special coatings other than the usual black paint.
Here's a brief reference in regard to how these collectors work and what their components are.
There's a glazing material used in the flat-plate collectors.
The material is transparent and the solar radiation courses down through this material in order to reach the absorbing plate.
Once enough radiation hits the absorber plate, it does its job: heating the plate.
The entire purpose behind generating and circulating that generated heat between the absorber plate & the glazing cover is to raise the temperature of the water or air that's flowing between the plate and the cover.
To diminish heat loss to other parts of the solar collector, the bottom and the sides of the device are covered with insulation.

2. **Evacuated tubes collector**

When talking about Evacuated Tube Solar Collectors, you'll find out that instead of one, there's an entire fleet of evacuated tubes needed to raise the temperature of the water by heating it.
Such tubes use an evacuated space or vacuum to trap the energy from the sun. The main application of these tubes is to minimize heat loss.
Here's a reference in regard to their components and working:
– A metal tube plays the part of the absorber plate.
– The absorber plate is directly patched with a heating pipe.
– The liquid that has to be heated flows inside the heating pipe.
– The job of the heating pipe is to show direction to the heat so that it can raise the water's temperature.
Easier said than done: it's not that simple to understand how the heat pipe allows the transfer of thermal energy from one point to another. Here the things are simplified.
– There are naturally two ends in a heating pipe.
– One end opens at the side of the absorber plate. It's where the heat is generated. Hence, this point is known as the heat end.
– The second end opens at the side of the cool water that's supposed to be heated. This end is naturally known as the cold end.
– At a certain pressure, the generated heat starts flowing towards the cold end; eventually, heating the cold water.

3.**Line focus collectors**

Better known as parabolic troughs, the Line Focus Solar Collectors use the same principle for heating water or air that other collectors do: collecting heat on an absorber plate and then transferring it to the water that's to be heated. The collector here is a rather effective parabola-shaped reflective material. The line focus collectors are extremely powerful solar collector types. Therefore, they are used for producing steam for large solar thermal power plants and not for domestic purposes.There is a pipe in the centre of this trough that functions as a carrier of water. The sunlight gathered by the reflective material is focused onto this central pipe which leads to the heating of the water.

Notably, the troughs productively produce heat energy from the sunlight, specifically the pivot troughs, which track the sun throughout the day for optimal trapping of sunlight.

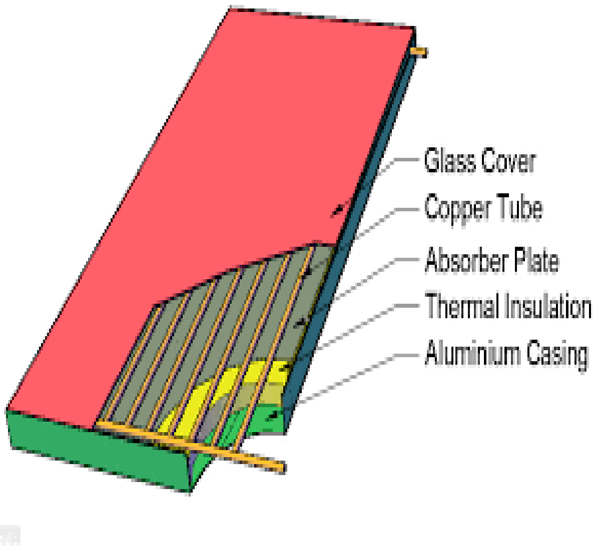
4. **Point focus or parabolic disc collectors**

The Point Focus Collectors are also large parabolic-shaped devices that are fabricated with highly reflective material.

These types of solar collectors again follow the same concept as that of other collectors: they directly focus all the collected solar energy onto a single point that's usually the absorber plate.

The heat generated is so substantial that it is utilised for operating Stirling engines.

These parabolic dishes can work as independent installations. For efficient collection, they constantly track the position of the sun. They can very well be used in tandem with concentrated PV modules.



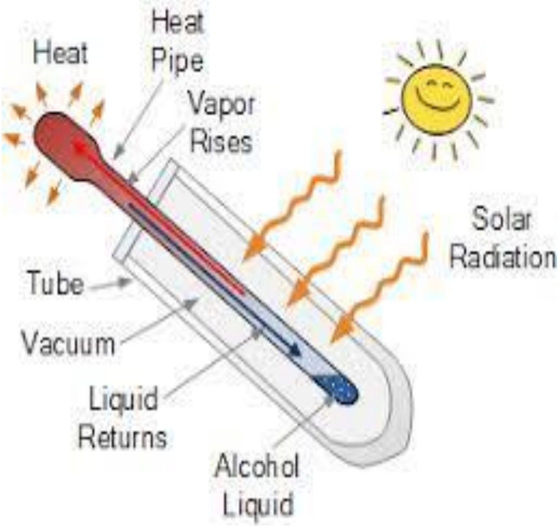
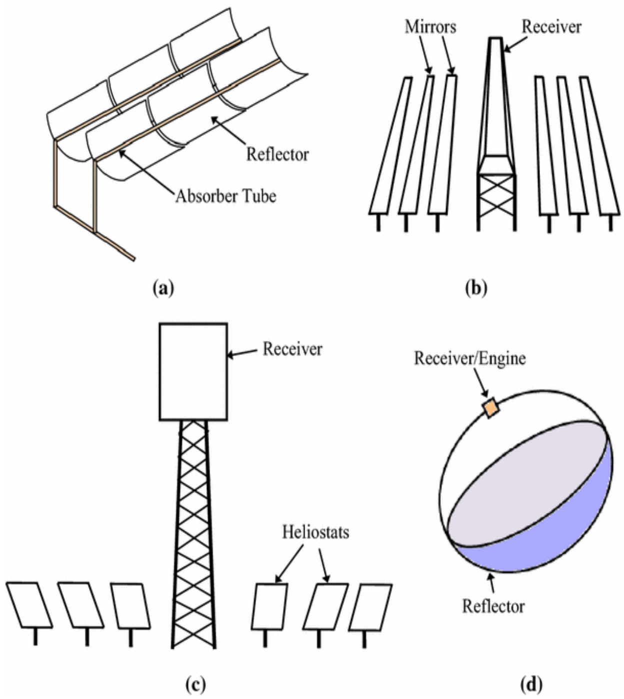


Fig. 2

Fig. 3



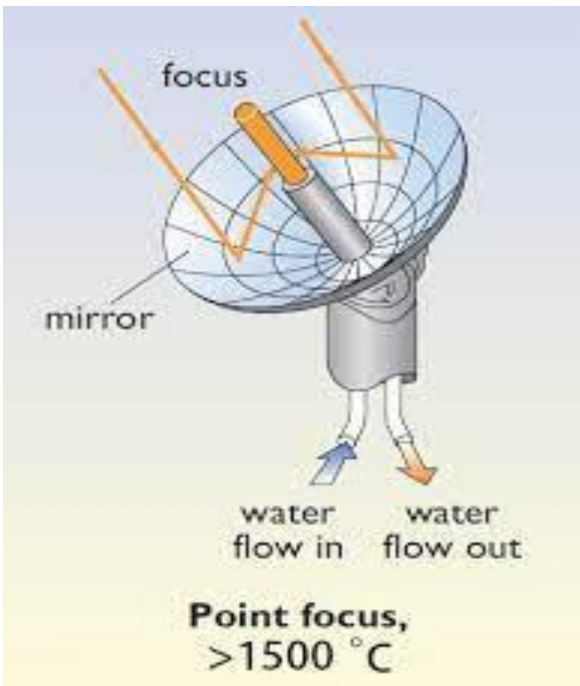


Fig .4

Fig .5

IV. Recent Advancements in Past Few Years

T.Jatau et al employed Constructal Method of design to optimise the geometry of the absorber numerically by seeking to minimise entropy generation subjected to the constraints of fixed absorber area and fixed volume of absorber tubes while allowing spacing between the tubes, the length of the tubes and the diameter of the tubes to vary.

M. A. Oyinlola et al. experimentally studied absorber plates with micro-channels for scaling effects and observed that Nusselt number was affected little by entrance effect and viscous losses.

R.W. Moss et al. Investigated numerous designs for an absorber for evacuated flat plate collector. The challenges encountered in designing an absorber for an evacuated collector included providing support for the glass cover as well as the necessity of the material being a low out-gassing one while providing better efficiency than conventional serpentine tube absorbers and at the same time the design must be easy to fabricate. Keeping this in view a flooded panel absorber was chosen and was fabricated from stainless steel sheets by hydroforming technique. CFDanalysis showed that halving the plate and having the inlet and outlet at diagonal corners could optimize the distribution of flow. FE analysis showed that the operational pressure could be withstood by a sheet of thickness 0.7 mm. Hydroforming pressure of 25 MPa was sufficient to mould the sheet of 0.7 mm thickness. Minimum safe height of the absorber in the evacuated collector was evaluated using distortion testing, figure 4. Authors have predicted 3% higher efficiency of the collector employing this design as opposed to conventional serpentine tube design.

H. Bhowmik et al. developed an FPSC with reflectors mounted on its two sides to concentrate diffuse as well as direct solar radiation on to the collector. The reflector panels were fitted such that their angle could be changed to track the sun. The authors report an improved efficiency of 10% over and above the conventional FPSC when tested with water heating prototype with the collector with reflectors at its core, figure 5. The collector with reflector invariably results in a higher outlet temperature of the fluid than the collector without reflector.The iron plate was used to make the collector and black paint was used as absorber coating and the final assembly was sealed off on top using transparent glass. Design of collector was done in a manner to obtain a parallel pattern of flow and constant rate of flow from entry to exit. Mercury glass was used for reflector panels. 25 l tank was utilized to supply water as working fluid.Using rotameters to measure and control the flow, flow rates of 0.1 l/min and 0.2 l/min were used for this experiment. The exit temperature of the fluid was seen to reduce with increase in volume flow rate. Thermometers were employed to measure fluid temperatures at entry and exit. Global average radiation was taken as 430 W/m2 . Collector surface area was 1.05 m2 and reflector surface area was 1.85m2 and the mirror was assumed to have a reflectivity of 0.9

Do Ango et al. investigated polymer absorbers for FPSC through numerical simulation and found that the thickness of air gap influences the collector performance and the optimal thickness was obtained as 10 mm. Efficiency was seen to vary proportionally with the mass flow rate of the fluid but elevated mass flow rates reduce outlet temperature obtained. Efficiency was unaffected by intensity of radiation but it was found to affect the outlet temperature and an approximately linear relation was seen.

F. Giovannetti et al explored and analyzed various spectral selective and high transmittance glass coatings which are based on transparent conductive oxides. Tin-doped indium oxide and aluminum-doped zinc oxide layers were analyzed. The spectral selective coating did not result in any enhancement of performance in single-glazed highly selective absorber collector; in fact, increased optical losses degraded the efficiency of the collector. But for other collectors, low emissivity coated glass resulted in improved performance. Thus single-glazed low selective absorber collector and double-glazed highly selective absorber benefit greatly from low emissivity, high transmittance spectral selective coating for the glass covers.

H. Kessentini et al. experimentally as well as numerically studied a design comprising of insulation of transparent material added between the absorber and the glass cover to minimize heat loss. They have added a system to protect the transparent insulation from overheat due to stagnation. The system uses a channel with a trap door which gets activated thermally. This has proven as an effective method of protection for transparent insulation material. The collector was then optimized through simulation and the optimized collector proved to be at par with existing designs in terms of performance while still being low cost. Experimental validation was done by performing tests on FPSC fabricated on the lines of conventional FPSCs with extra insulation of transparent material inserted between the glass cover and the absorber.

Another recent and major development in the field of solar collectors in general and FPSCs in particular has been the use of nanofluids to enhance the heat transfer to the working fluid, which has not been covered in this paper. Nanofluids are a special type of fluid which can be used as working fluid in solar collector systems with and without heat pipes. They are synthesised by dispersing a small quantity of solid nanoparticles often less than 100 nm in a base of traditional working fluids such as water or ethylene glycol. A rigotous treatment of the models for explaining the heat transfer augmentation has been presented by S.M.S Murshed et al . S. K. Verma et al. , M. A. Alim et al. , A. Zamzamian et al. have experimentally as well as analytically investigated various metal oxide based nanofluids for solar collector applications.

IV. CONCLUSION

This paper presented a general review of design advancements in FPSCs in the past few years. Studies conducted showed a great scope for improvement in the design of FPSC to make it suitable for wider adoption by making it more efficient. Techniques covered in this paper include redesigning of absorber plate for efficient flow with the maximum transfer of heat from absorber to working fluid. The use of optimization techniques to evaluate the optimal dimension of absorber and manifolds prove to be effective. Coatings for glass covers, use of transparent insulation between absorber and cover may be used to minimize heat loss. This paper will be helpful in looking for future fields of research to pursue.

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