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Experimental Investigation of Solar Flat Plate Collector Using Ceramic Coated Panel

Ayyappan Rajagopal*[1], Vijayan Gopalsamy,[2] R.Karunakaran[3] Naveen Kumar Rajendran[4], Muniraj Gowran[5],
[1-5]*Department of Mechanical Engineering,*
[1,4,5]*Aksheyaa College of Engineering, Pulidivakkam, Kancheepuram District, Tamilnadu, India*
[1]prof.ayyappan@gmail.com,
[4]nvnmech93@gmail.com,
[5]raju7258raju7258@yahoo.in.
[3]*University College of Engineering ,Thirukuvalai,Thiruvarur District,Tamilnadu, India*
[2]*KSK College of Engineering and Technology, Kumbakonam, Tamilnadu, India.*
[4]viji_laker@yahoo.co.in.

ABSTRACT: *In the rapidly changing world the source of power production is mainly established on the conventional source of energy. But due its depletion and its impact on the environment the prevailing source of energy does not meet the energy required for the forthcoming decades. There arises a need of finding an alternate source of energy. This physical exertion focuses on cost effective method of utilizing the renewable and clean energy. Study has been done on different existing flat plate collector's behaviors and compared to reduce the cost of collector. To carry out this the ceramic coated tiles are used to diminish the cost of panel, insulation, maintenance, durability and its life considerations. The investigation presents optical and thermal properties of the collector, which are calculated by using experimentation. The cost of prepared flat collectors is economical and beneficial which is designed, fabricated and tested on the base of the locally available materials and presented in this critique.*

Keywords: *Solar Energy, Flat Plate Collector, Ceramic Coated Tiles, Solar Radiation, Productivity, Cost, Reliability*

I. INTRODUCTION

A. Solar Energy

In the competitive and technological world, energy requirement is the heart of the industrial and domestic needs nowadays. But due to the faster depletion of the conventional energy resources and its adverse effect on the environment there is a need to switch over for an alternate clean and green energy to protect the earth. As a result, considerable research and development activities have taken place to identify reliable and economically feasible alternate clean energy sources. The sun releases an enormous amount of energy to its surroundings: 174 PW (1 PW=10^{15} W) at the upper surface of the atmosphere of the earth [1]. So the preference automatically goes to solar energy which is abundantly and naturally available everywhere throughout the year. This can be collected by means of the simple collector arrangements for energy requirements and needs such as production of electricity, heating, air-conditioning requirements and industrial needs. The available source of conventional energy cost cannot affordable due to its depletion, more cost to extraction, purification, storage, transportation, usage, equipment and pollution control systems. This arises more focus on the solar energy to satisfy energy demand in localized areas.

B. Solar Collectors

There are variety of solar collectors are available in the market which do not satisfy the needs of the consumers due to its cost, quality, durability, reliability and performance characteristics. This is the challenging task in the past decades even though it satisfies the other factors cannot afford that much of cost due to longer payback period and higher initial investment cost. After the review of various collectors its merits, demerits and performance characteristics make to carry out this project. The existing solar energy collectors cost impending on it is much more and over a shorter life span of about 15-20 years. This arises the need of newer sustainable materials to overcome the limitations [1].

C. Ceramic Materials

The ceramic materials are the cheaper, affordable obtained as a byproduct from industrial waste which can be used as a construction material in many applications and having the following mentioned properties. The ceramic possesses the properties such as chemical, physical, mechanical, thermal, electrical, and magnetic properties that distinguish them from other materials, such as metal, metal alloys and plastics. During the manufacture customizes ceramics by controlling the type and amount of the materials used to make them [2]. Apart from this, ceramics are more resistant to corrosion than plastics, metals and its alloys. Ceramics generally do not react with most liquids, gases, alkalis and acids. Most ceramics have very high melting points and certain ceramics can be used up to temperatures approaching their melting points.

The world low cost means not only “low cost” solar collector materials, but also it has long life. All ceramic collectors have characteristics of low cost, long life time and good thermo stability [3].

D. Heat Transfer Medium And Enhancements

There are varieties of heat transfer mediums available in the market such as solids, liquids, gases and combination of the foresaid forms. To store and transport the heat energy absorbed from the solar collectors, it is essential and cheaply available, eco-friendly sources such as air, water which are used in many of the cases. In low temperature applications the gas or fluid medium is used to transfer the heat energy from panel to workspace. In high temperature applications the combinations of above or the phase change materials is used. In recent centuries, the solvents mixture, salt solution metal suspended fluid mediums such as Nano fluids and colloidal solutions have been used. Such kind of heat transfer mediums improve the effectiveness in the considerable level conversely increase in the synthesis and overall cost of the system.

Phase-change material (PCM) is a substance with a high heat of fusion which is melting and solidifying at a certain temperature also capable of storing and releasing large amounts of energy. Heat is absorbed or released when the material is changed from solid to liquid and vice versa. These systems are not very efficient due to the unavoidable losses due to conduction, convection and radiation caused by the temperature difference apart from problems because of leakages through joints and corrosion [4].

E. Insulators

The collector housing is highly insulated at the back and sides to minimize the heat losses. Although there are still some collector’s heat losses due to the temperature variation between the absorber and atmospheric air that results to convection and radiation losses. The convection losses are caused by the angle of inclination and the gaps between the glass cover and the absorber plate, while the radiation losses are caused by the exchange of heat between the absorber and the environment. The absorber plate which covers the full aperture area of the collector must perform three functions: absorb the maximum possible amount of solar irradiance, transfer this heat into the working fluid at a minimum temperature difference and lose a minimum amount of heat back to the surroundings. All the above mentioned functions must be performed to reduce the heat loss and maximize the efficiency of the collector panel.

Flat-plate collectors must be insulated to reduce conduction and convection losses through the back and sides of the collector box. The insulation material should be dimensionally and chemically stable at high temperatures, and resistant to weathering and dampness from condensation. Usually, glass-wool insulation 10 cm thickness is recommended. It would be between if the insulation also could contribute to the structural rigidity of the collector, but more rigid insulating materials are often less stable than glass-wool. Temperatures in flat-plate solar collectors can be high enough to melt some foam insulations, such as Styrofoam. And some foam gives off corrosive frames at high temperatures, which could damage the absorber plate [5].

Some of the insulating foams and materials will react with the collector structure and corrode the materials used for absorbance. Some of the insulation will react and melt at elevated temperatures, this leads to the problems to be unsolved. The effectiveness is mainly depends on direct or diffuse radiation, environment, temperature inlet, absorber material and blackness degree of selective surface and quantity of isolation material. In general, most of the application ceramics are the well-known refractory materials which retain the heat inside the chamber.

F. Tracking Systems

The tracking system is used to collect the solar irradiation and to reduce the reflective heat transfer losses by tracking retain the collector absorbing capacity to a maximum level. The solar tracking systems consist of the sensors and actuators to rotate the entire collector to maximize and perpendicular to the solar irradiation to avoid the losses due to the emissive power and reflectivity of the glazing materials.

Firstly the plant possesses sun tracking system on both surfaces. The azimuthal and zenithal sun tracking systems increase the efficiency of the solar collector. Therefore there's no solar energy loss in this plant. From energy point of view the plant can profitably work at both solar radiations (direct and diffuse solar radiation). Besides the technical and energy prevalence's the equipment belongs to economical priority[6].

When the average annual solar energy radiation intensity obtained at the optimum angle of inclination was compared with that from the horizontal zero degree position, 4.23 % average yearly increase in solar energy radiation intensity was achieved. Also an average annual solar energy gain of 3, 70,670 MJ/m^2, over the horizontal position, was achieved, when the flat plate was inclined at optimum angle for harnessing maximum solar radiation intensity [7].

Since the optimum angle of inclination varies on day by day. Solar collectors should be mounted on telescopic legs for easy adjustment of the collectors to the determined optimum angle of inclination for the day in question.

Flat-plate solar collectors are designed for applications requiring energy delivery at moderate temperatures. They utilize both beam and diffuse solar radiation, and do not require sun tracking. The solar air heater occupies an important place among solar heating systems because of minimal use of materials. Furthermore, the direct use of air as the working substance reduces the number of required system components. The primary disadvantage of solar air heaters is the need for handling relatively large volumes of air with low thermal capacity as working fluid [8].

II. EXPERIMENTAL SETUP

The proposed solar collector is made up of highly hardened and toughened ceramic tiles which are mounted on the wooden structure for its mobility, transportation and angular variations. It is mounted on a steel frame as shown in Figure-1 and Table-1 which provide the complete material specification. The finned copper collector tube is fitted inside by means of the necessary support and a leak proof wall arrangement is made to collect and transfer of the solar energy. The fins are used to enhance the heat transfer between the primary and secondary medium [9-11]. The top most layer is covered with highly reflective inner and absorbing outer surface. A glass is fitted on the top of the panel to absorb the heat energy by the finned tube arrangement provided in it. Tube is kept welded with the fins and set in a zigzag position to enhance the heat transfer and positioned in a double pass coil unit to absorb the maximum amount of heat in solar panel. The absorbing medium such as air and water are used as the heat transfer medium from the collector to the secondary unit or storage unit. The thermometer (0-350ºC) is fitted inside the collector to measure the temperature of primary heat conducting medium. The another two thermometers are fitted in the inlet and outlet of the finned tube to measure the temperature difference between before entering and after leaving the finned tube of collector panel. The quantity of fluid (0.2 Liters per minute) concern is maintained constantly.

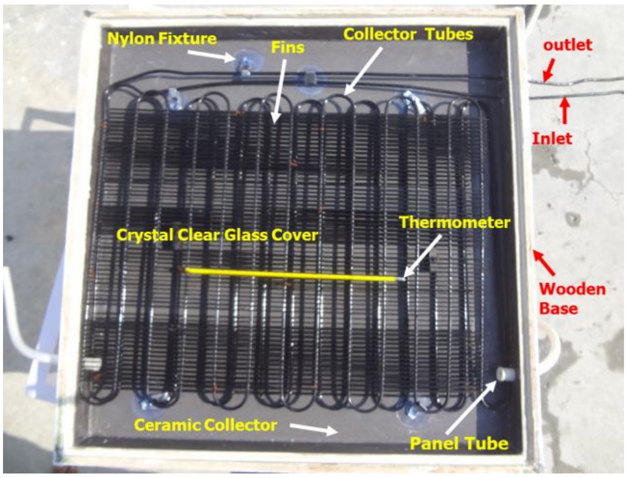

Fig. 1. Experimental setup of solar collector

III. RESULTS AND DISCUSSIONS

From the desertion the values are plotted between time and temperature which show that the temperature rises with the time up to noon then it slowly reduces. In this prediction the solar energy collection is based on the type of fluid medium, material, thermal conductivity, time of exposure, incident angles, isolation and absorptive materials. This shows that the increase in thermal potential is evenly distributed to the collecting fluid. The ceramic collector acts as the insulator and recuperates the energy and retained in the collector for a longer period in the collector itself. From this, the results infer that the double walled glass may be to reduce the conductive and convective losses in collector plate. The collector itself acts as the accumulator during the fluctuating demands. During the idling period the temperature remains constant for a prolonged time. This indicates that energy collected in the panel is distributed and having lesser heat losses to the surroundings even though the ceramic having the thermal conductivity of 2.86 kJ/m K. This can be reduced further by means of the vapour barriers such as water proof cement, thermal insulating cements, salt contents and integration with the reinforced building materials. This can neglect the cost of the isolated sensible heat collector and storage devices. This leads to the most economic and beneficial collector of scattered energy.

TABLE I
MATERIAL SPECIFICATION

S.No	Materials	Specification
1	Ceramic collector length	580 Mm
2	Ceramic collector width	580mm
3	Ceramic collector height	42 mm
4	Recess between coil and collector	100 mm on each side
5	Tube inner diameter	4 mm
6	Tube outer diameter	6 mm
7	Tube length (aluminium alloy)	15,682mm
8	Fin diameter	2.5 mm
9	Fin length (aluminium alloy)	560 mm
10	Number of tubes and pitch	28 &47.5 mm
11	Number of fins and pitch	56 &7.5 mm
12	Base plate thickness (ceramic tiles)	10 mm
13	Supporting plate thickness(wood)	12.5 mm
14	Reflective glass thickness	5 mm

From the results the following advantages over the existing collectors are noted for the further development and suggested to implement in large scale productions. In addition to that integration of flat plate collectors with collector such as Fresnel, concentrated collectors to produce higher temperature gradients. Due to the elevation in temperature the difference is minimized by the flat plate's acts as a booster from the lower gradient levels.

- Lesser construction cost for acquiring the same amount of energy.
- Elimination of isolated sensible heat collectors.
- Reduction in the constructing material.
- Cheaper and ecological benefits.
- Relies with the life span of building materials.
- Shorter pay back due to optimized material cost.
- Vast collection of scattered energy is possible.

Creep occurs naturally by means of external forces such as forces due to self-weight, thermal stresses acting on a static member. This phenomenon is reduced because there is a thermal barrier in between collector and building material. The collector almost absorbs the heat for energy conversion and needs. The remaining heat is prevented by means of tiles, salt mixture and insulations. Therefore, the significant reduction in the thermal expansion of building material leads to the reduction in cracks due expansion, contraction and thermal stresses. This leads to considerable increase in the life of building.

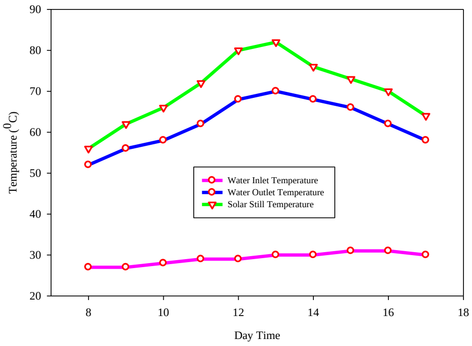

Fig. 2. Comparison of inlet, outlet and solar still temperature

IV. CONCLUSIONS

By consolidating the research and investigation result this becomes the best solution against the other type of concentrated collectors, storage devices and solar tracking systems. The ceramic plate collector embedded systems are more economic, cheaper, reliable, eco-friendly, durable, hassle free, dual purpose system for energy requirement and shelter in the modern world. This exploits the energy crisis and satisfies the needs of the forthcoming decades. Moreover, it integrates well with the building materials and reduces the erection time and cost of both the construction materials. By this life span of both panel and building are also drastically increased. The reductions in thermal stress is acting on the supporting materials and deformation due to creep is reduced. Constructions of such integrated panels meet the energy needs and emphasis on much wider area to collect the scattered source of energy with cheaper materials. This paper leads to meet energy wants with most efficient, economic and promising pay back in shorter span are the future scope of this outcome.

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