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Performance Analysis of Flat Plate Solar Water Collector using Trapezoidal shape and Semi-circular Tubes: A Review

Vipin.B.Nanhe[1], R. D. Gorle[2]

M. Tech. (Heat Power Engg.) Student, Deptt. of Mechanical Engg, Dr.Babasaheb Ambedkar College of Engineering and Research, India[1]

Assistant Professor Deptt. of Mechanical Engg, Dr.Babasaheb Ambedkar College of Engineering and Research, India[2]

Abstract - *The flat plate collector forms the heart of any solar energy collection systems designed for operation in the low temperature range, from ambient to 60°c, or the medium temperature range, from ambient to 100°c. A well engineered flat plate collector delivers heat at a relatively low cost for a long duration. Generally flat plate collector consist of arrays of circular cross sectional tubes are bonded to the absorber plate to transfer of heat from absorber tube to working fluid. When using semi circular type tube blow to the absorber plate, the area of intimate contact is increases between fluid and absorber plate and also resistance due to adhesive is decreases. Also use of flat plate collector with trapezoidal shape with four sided mirror provision enhanced solar heat collection a better matching of solar collection to load requirements and acceptable efficiencies at higher operating temperatures. Due to this reason performance of solar flat plate collector is increased.*

Keywords *– solar flat plate collector. Trapezoidal shape, semi-circular tubes, absorber plate.*

1. INTRODUCTION

In recent years solar energy has been strongly promoted as a viable energy source. One of the simplest and most direct applications of this energy is the conversion of solar radiation into heat. Hence way that the domestic sector can lessen its impact on the environment is by the installation of solar flat plate collectors for heating water. Although it should be said that some of these collectors have been in service for the last 40-50 years without any real significant changes in their design and Operational principles. A typical flat-plate collector consists of four components (i) absorber plate (ii) tubes fixed to the absorber plate (iii) the transparent cover (iv) the collector box. The collector plates absorb the maximum possible amount of solar irradiance and transfer this heat to the working fluid which is flowing in absorber tube. The fluid used for heat transfer generally flows through a metallic tube, which is connected to the absorber plate. The absorber is usually made of metallic materials such as copper, steel or aluminium and surface is generally black. The collector box can be made of plastic, metal or wood type insulator to prevent heat loss and the transparent front cover must be sealed so that Heat does not escape, and the collector itself is protected from dirt and humidity. The heat transfer fluid may be either water or water with antifreeze liquid. Still the heat losses due to the temperature difference between the absorber and ambient air result in convection and radiation losses. The main advantage of a flat plate collector is that it utilizes both beam and diffuse components of solar radiation. Efficiency of flat plate collector depends on the temperature of the plate, ambient temperature, solar insolation, top loss coefficient, emissivity of plate, transmittance of cover sheet, number of glass cover.

2. REVIEW OF WORK CARRIED OUT

Dr. Karima E. Amori et al.[01] a study was carried out for thermal improvement of solar water system using accelerated tubes in flat plate collector This study includes a comparison between the performances of two locally fabricated similar flat plate solar collectors. One of these collectors is a new design of accelerated absorber, its risers are of converging ducts (the exit area is half that at the entrance). The other collector is of conventional absorber (its risers have the same cross sectional area along its length). Results show that a considerable enhancement of thermal performance approximately (60%) of absorbed heat (useful gain) at solar noon is obtained for the new design in comparison with the conventional type.

Y.Y. Nandurkar and R.S. Shelke et al.[02] conducted experiments in which reducing area of liquid flat plate collector by increasing tube diameter and reducing riser length. Solar flat plate collector having increasing diameter of copper tube of flat plate collector with integral fins performances is better than the ISI flat plate collector. The present work is an study on the comparative performance analysis of ISI flat plate collector with modified flat plate collector. It is found that the modified flat plate collector with increase in diameter of test

section, Nusselt number and Reylonds number is increased with second power of tube diameter.

Sunil.K.Amrutkar, Satyshree Ghodke, Dr. K. N. Patilet al.[03] Had performance studies on Solar Flat Plate Collector Analysis. The objective of present study is to evaluate the performance of FPC with different geometric absorber configuration. It is expected that with the same collector space higher thermal efficiency or higher water temperature can be obtained. Thus, cost of the FPC can be further bring down by enhancing the collector efficiency. A test setup is fabricated and experiments conduct to study these aspects under laboratory conditions (as per IS standard available for the flat plate collector testing).

Thundil Karuppa R. Raj et al.[04] et al investigates a new solar flat plate collector which is of sandwich type. The new type of collector is the water sandwich type collector which is made by bracing two corrugated metal sheets on one another. The absorber is made of 2 sheets of GI (1 mm) with integrated canals, painted silica based black paint. The outer casing which provides mechanical strength to the equipment is insulated to reduce the heat losses from back and sides of the collector. The new collector is differ is the absence of heat carrying metallic tubes. The working fluid is made to pass through the channels that are formed when two corrugated metal sheets are braced one over another. Efficiency of the flat plate conventional is 24.17 and efficiency of the new collector is 20.19%.

J.S.Khatik, S. V. Yeole, Juned A. R. Aet al.[05] conduct an experimental work on the performance of newly proposed absorber plate having concavities and compared with the conventional absorber plate . Experiments were conducted on two absorber plates separately. In one plate, small cavities were produced while the other plate was kept simply smooth. Making concavities in the plate increases the surface area of the plate the results shows that there is an improvement in the heat transfer rate. The heat transfer rate is increased by 5.12%. It shows that the increase in outlet temperature due to the provision of concavities which increase the diffusion area for radiation reducing the reflection losses. .

A.T. Fatigun et al.[06] conduct experiment in which the effect of tube spacing on the performance of a flat plate collector is compares. Two same aperture area of solar flat plate collector is compare of average adjacent tube spacing of 11 cm (A) and 20 cm (B). Average of 11 cm spacing between adjacent lines yielded 15 turns while 20cm average line spacing yielded 9 turns of tubing per Flat plate. The efficiency of collector (B) was found to be significantly higher than that of collector (A), i.e. 10% and 21% was obtained for collectors (A) and (B) respectively.

Ljiljana T. Kostic et al.[07] proposed an optimum position for the reflectors to improve the thermal efficiency of flat plate collector SWH. For that purpose they were conducted study on thermal collectors with and without flat plate solar radiation reflectors.

D. C. Larson et al.[08] Had experimental investigation on Optimization of Flat-Plate Collector-Flat Mirror Systems. the use of a flat plate collector with mirror provides enhanced solar collection, a better matching of solar collection to load requirements and acceptable efficiencies at higher operating temperatures.

K. Sarath kumar et al.[09] manufactured the model on the concept of advanced solar water heater i.e. conventional solar water heater with concentric collector. They tested the model in two stages. In the first stage the solar water heater was tested without concentrator and in second stage with concentrator. They conducted experiments in two different stages. In first stage the experiment were conducted without parabolic concentrator. Then concentric collector is attached to it and experiment was conducted. The obtained results show the efficiency of advanced solar water heater is 15.3 percent higher than conventional flat plate water heater.

3. METHODOLOGY

A solar water flat plate collector performance influence by the number of parameters such as selective surfaces, numbers of covers, spacing between covers and absorber plate etc. In this study the shape of flat plate collector considered to be trapezoidal in shape with four sided reflective mirrors provision. Also shape of tube is considered to be semi circular in cross-sectional area attached to the absorber plate so that area of absorbing surface is more than that of a circular tubing system in solar flat plate collector.

3.1 Conventional flat plate collector:-

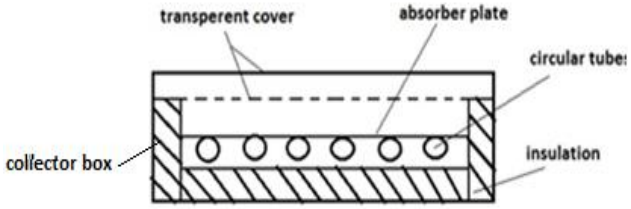

Fig-1: conventional flat plate collector

As from fig.1 shows conventional type flat plate collector with rectangular in shape with circular tubes attached to the absorber plate. in this type the resistance to heat flow to the tube from the plate may be consisted of three components;

1. The resistance due to the adhesive used for attaching the tubes to absorber plate = $\frac{1}{C_a}$

2. The resistance due to the wall thickness of the tube = $\frac{1}{C_w}$

3.The resistance due to the heat transfer coefficent at the inner surface of the tube = $\frac{1}{D_i h_{fi}}$

By considering this three resistence useful heat gain is given by,

$$Q_u = \frac{T_b - T_f}{\frac{1}{C_a} + \frac{1}{D_i h_{fi}} + \frac{1}{C_w}}$$

3.2 Trapezoidal shape flat plate collector with semi circular tubes:-

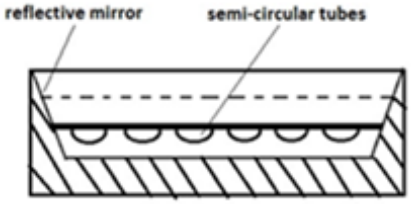

Fig-2: Trapezoidal flat plate collector with semi circular tubes

In this study flat plate collector with semi-circular tubes and collector box with trapezoidal in shape fig.2 is modified. By using this novel technique

1. The resistance due to the bonding material between the plate and the tube = $\frac{1}{C_a}$

2. The resistance due to the wall thickness of the tube = $\frac{1}{C_w}$

this two resistence are eliminated. Also use of flat plate collector with trapezoidal shape with four sided mirror provides enhanced solar heat collection. **Dci=1.414Di**, is the diameter of semi circular tube and useful heat gain (Qu) by tube is increase.

By considering this useful heat gain is given by,

$$Q_u = \frac{T_b - T_f}{\frac{1}{D_{ci} h_{fi}}}$$

3.3 Experimental setup:-

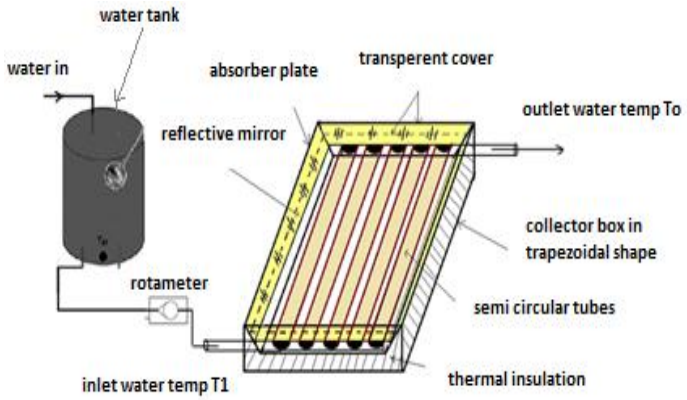

Fig-3: Experimental setup

The basic components of the experimental setup in this study are water flow, temperature measurement and flat plate solar collector in trapezoidal shape with four side reflective mirror. The water flows through absorber tubes and brings together the heat produced by the solar radiation that reaches to the absorber plates shown in Fig. owing to high thermal conductivity of absorber surface, the heat transfer from the back plate and water fluid inside tubes will increase.

The solar collectors have four essential static components: absorber plate on top, collector plate and semi-circular absorber tubes made from copper and welded to the absorber plate. The most important component of a solar collector is the absorber plate. In this study, the absorber plate has high conductivity and at constant high temperature. In order to improve the heat transfer from the absorber plate to the flowing water, the absorber surface needs to be enlarged to maximize contact surface of water tubes. In order to do this in this study, shape of tube is considered to be semi circular cross-sectional area. The tube attached to the absorber plate is semi circular, so that area of absorbing surface is more than that of a circular tubing system in conventional solar flat plate collector. So due to this modification the performance of flat plate collector is increase.

4. CONCLUSION

The flat plate collector with semi circular cross sectional tube welded to absorber plate and collector box in trapezoidal shape with four sided mirror provision have absorbed more heat than that of circular cross-sectional area tube with conventional rectangular collector box, which increase solar heat collection and due to increasing absorbing area of tube, reducing the resistance due to the bonding material between the plate and the tube and the resistance due to the wall thickness of the tube. So, this method improves the efficiency of flat plate collector.

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