Recent Advancement in a Flat Plate Solar Thermal Collector using Heat Enhancement Techniques: Review

Jayshree Raut[1] Dr. P. V. Walke[2]
[1]M.Tech Student
[1,2]Department of Mechanical Engineering
[1,2]G.H. Raisoni College of Engineering, Nagpur-16, Maharashtra, India

Abstract— This paper provide recent developments carried out on solar collector for heat transfer enhancement by using passive heat transfer techniques, which includes inserts, metal foam, geometry of absorber plate and other various things that have been done for performance improvement of the solar collector. This paper corresponds to an extensive study of the research carried out on solar thermal collector. In the present paper, experimental and theoretical developments in the field of thermal solar collector have been studied thoroughly.

Key words: Heat Enhancement Techniques, Solar Thermal Collector, Thermal Efficiency

I. INTRODUCTION

The vast research and development is going on in solar energy utilization, the increasing energy demand and depleting conventional energy sources forces us to adapt clean, green and free of cost renewable energy. Solar energy is one such alternative; the main component of solar thermal energy is solar collector. The solar thermal collector is one kind of the heat exchanger which absorbs the solar incoming radiation and exchanges the heat to the fluid that may be water, air or oil which is passing though the collector. The flat plate solar collectors were widely used for domestic water heating, space heating and industrial processes or applications. A simple flat plate solar thermal collector consists of absorber plate, riser, header tubes, glass cover (transparent) and the collector box.

Nowadays lots of work have been followed out to improve the performance of a flat plate solar collector by means of a set of heat augmentation techniques. Enhancement techniques are classified into two groups: “active” and “passive” techniques. In active heat enhancement technique external power is needed to enhance heat transfer and in passive heat enhancement technique no external power is required. Passive heat transfer technique is more popular than the active technique because of its simpleness and pertinence in many applications. The passive heat enhancement techniques mainly consist of extending or coating the heat transfer surfaces, using various heat augmentation devices to generate swirl, vortices in the flow, to increase the roughness adding projections in surface of the pipe, inserting grooves, helical ridges into the inner surface of pipe, or twisting the pipe etc. [27]. The majority of works carried out to improve the performance of flat plate solar thermal collector in the past to obtain heat augmentation such as, wire coil insertion [1], twisted tape insertion [2], inserting conical ridges, twisted strip and coil-spring wire [18], metallic mesh insertion, multiple metal-foam blocks [7], providing artificial roughness, multiple fin array, the double pass channels, v grooves absorber, porous media, porous disc receiver, finned receiver, and so on [8-10]. Also the performance of the flat plate solar thermal collector can be enhanced by minimizing heat losses from top surface of the solarcollector.

The efficiency improvement of the flat plate solar thermal collector by using passive heat enhancement technique can ultimately increase its outlet temperature of fluid and reduce its size.

II. LITERATURE REVIEW

Alberto García, et al. [1] investigated the heat transfer augmentation in the flat plate solar water collector using wire inserts experiment were performed with different mass flow rate values. The enhance collector was weigh against with the standard solar thermal collector under same operating condition. It was concluded that wire-coils can be inserted in the riser tubes of flat plate solar water collectors for improving its heat transfer rate and thermal efficiency. By inserting wire-coils the collector efficiency was increase by 14 -31%, counted on mass flow rate. As the mass flow rate increases the heat transfer enhancement potential decreases.

A Kumara, et al. [2] studied the heat transfer augmentation in a flat plate solarwater heater. Were they have used twisted-tape inserts of twist pitch to tube diameter ratio varying from 3±12, for various mass flow rates. The heat transfer rate increased by using the twisted-tape insert in flat plate solar collector was 18±70%, but the pressure-drop rise by 87±132%, as compared to standard collectors. It was found that the performance of solar water heater with twisted tube insert inside the riser tube performed better than the standard solar heater and observed that heat losses are minimized due to low temperature of plate thus performance of the solar water heater with twisted tube insert increase by 30% as compared with the standard solar collector for same the conditions. It was concluded that the twisted tape collector performed remarkably better for low Reynolds number (Re = 12000), the performance of the solar collector was monotonous if Reynolds No. increases beyond 12000.

Alireza Hobbi, et al. [3] studied a flat plate solar water collector with the different passive heat enrichment devices like twisted-strip, coil-spring-wire, conical-ridges etc. and also analyzed its impact on performance of a flat plate solar collector. And they have concluded that the passive heat enhancement devices are ineffective. There is no any enhancement in heat transfer rate in the studied range and geometry.

S. Vijayakumar, et al. [4] studied the heat transfer enhancement in flat plate solar collector. Here they had used two types of inserts wire coil and twisted tape. It is inserted into the tubes to create a turbulence and continuous swirling flow along the tube wall. By using inserts the heat transfer rate was increased by 18% to 70%. The performance of the enhanced solar water heaters perform better than the standard solar water heater. They noticed that heat losses are decreases. And the thermal performance increased by 30% as compared with the standard water heaters for the same working conditions.

S. Jaisankar, et al. [5] studied the Heat transfer enhancement in a thermo-siphon solar water heating system using helical twisted tapes of various twist ratios. They studied the Heat transfer enhancement in a thermo-siphon solar water heating system using helical twisted tapes of various twist ratios. The overall thermal performance of enhanced collector increases with increase in solar intensity.

R.Herrero Martin, et al. [6] did simulation on a flat plate solar water collector using TRNSYS as simulation tool with wire inserts in riser tube. The numerical simulation methodology provides the thermo-hydraulic flow behavior of standard and enhanced (tube on sheet) solar collectors. This stimulation tool evaluates the local losses, friction coefficients and Nusselt numbers as functions of the working parameters. The standard and enhanced collectors (tube on sheet) were simulated under the same ambient, radiant and working conditions. The standard efficiency curves according to UNE-EN 12975-2 are provided. Thermal efficiency of enhanced collector was found to be higher by value 4.5% as compared with the standard solar thermal collector. A parametric analysis of fluid and its flow characteristics with heat transfer improvement were carried out. The simulations were performed for different operational fluids like water, propylene glycol and water mixtures for different mass flow rate vary from 15 to 120 lit/hr m2.

Po-Chuan Huang, et al. [7] they did a numerical investigation of forced-pulsating convection flow in parallel plate channel of solar collector equipped with multiple foam metal blocks. Inserting metal foam blocks at the inner wall of absorber and flow pulsating is an efficient method for improving heat transfer between the solar absorber plate and running fluid.

G. Iordanou, et al. [8] analyzes thermal behavior of a flat plate solar collector by inserting aluminum grid in its channel. And the same was compared with conventional or standard solar collector. There is an enhancement in heat transfer coefficient by 9% in the collector with the metallic insertion and also enhancement in outlet temperature of the working fluid.

A. Bashria, et al [9] did the analysis of thermal behavior of single and double passes v-grooves solar collector. The solar collector was with and without porous media. And they concluded that the double pass flow mode solar collector was more efficient by 4-5% than the single pass v-groove solar collector. Also they investigated that the efficiency of the double pass mode v-groove absorber solar thermal collector with porous media was 2-3% more than the without porous media double pass mode v-groove absorber solar collector, and 7% more efficient than single mode.

K. Sopian, et al [10] evaluated double-pass solar collector thermal efficiency, were the double-pass solar collector was with porous and also with nonporous media in lower channel. And they had concluded that the presence of the porous media in double pass increases outlet temperature. Therefore the thermal efficiency of a system increases. The thermal efficiency of double pass solar thermal collector with porous material is approximately 60–70%.

Sunil.K.Amrutkar, et al. [11] evaluated the performance of a flat plate solar collector as per IS standard for water heater with various manufactures. The absorber sheets geometry and shape of the flat plate solar collector were occupying lesser space for a given heat collection surface area than required by conventional flat plate solar collector which have straight absorber sheets. With this comparison it was found that there is a still scope for lowering occupied space by making effective heat collection surface area greater in a given space.

Raj Thundil Karuppa R et al. [12] investigated new and inexpensive type of solar water heater collector; the collector is of sandwich type. The absorber plate is made of 2sheets GI (1mm) with integral canals painted in silica based black paint. Experiment was carried out to test the performance of both the water heaters under water circulation with a small pump and the results are compared. And it is noticed that the modified system reached upto satisfactory levels of 20.19% and it was economical and simple to manufacture.

B N Mankar [13] investigated the thermal behavior of flat plate solar collector with the use of aluminum metal blocks on absorber plate and forced pulsation of incoming fluids. Experiments were carried out for steady state and for pulsating flow conditions. There is improvement in thermal performance for modified flat plate collector. Time required to heat fluid was less than conventional collector.

Alberto Garcı´a [14] performed experimental study on three wire coils of different pitch inserted in a smooth tube in laminar and transition regimes. Isothermal pressure drop tests and heat transfer experiments under uniform heat flux conditions were carried out. For Re> 200 wire coils did not enhance heat transfer with respect to smooth tube. For 200<Re>1000, increase heat transfer. For Re =1000 wire inserts, enhanced the heat transfer coefficient up to eight times higher than as compared with the standard thermal solar collector.

P. Sivakumar [15] performed the experimental analysis of flat plate collector by changing number of riser tube and its arrangement in zigzag pattern. Experiments were conducted using copper tube in header and riser with different dimensions. When number of riser tube increases the efficiency of solar water collector was 59.09% and in zigzag arrangement the efficiency was 62.90%.

Alok Kumar et al. [16] analyzed performance of flat plate solar thermal collector by using semi circular cross sectional tube. In standard flat plate collector a circular cross sectional tube were fitted to absorber tube so that heat may transfer heat from absorber tube to working fluid. And in this modified system a semi circular cross sectional tube were fitted to the absorber plate. In case of semi circular type tube, the area of contact is increases between operating fluid and the absorber plate. Also the resistance due to adhesion was decreases and the performance of a flat plate solar collector was improved.

B Kundu et al. [17] they did a performance analysis and optimization of a flat plate solar collector of different geometry absorber plates and conclude that a trapezoidal profile absorber plate having optimum efficiency. The trapezoidal profile is a better choice as solar thermal collector, as the solar energy transfer rate is higher. Whereas this profile is not much popular as it is difficult to manufacture.

Y. Raja Sekhar et al. [18] evaluated flat plate solar collector with single cover glass heat losses coefficients. And they concluded that the emissivity of the absorber plate of solar collector had a significant impact on top heat loss coefficient whereas there is no any significant impact of tit angle for the same. The efficiency of flat plate solar collector rises with rising ambient temperature.

Mirunalini Thirugnanasambandam et al. [19] studied the solar thermal technologies; they analyze the existing designs of solar thermal technologies and fabrication of innovative designs with suggested solar thermal technologies.

Ziqian Chen [20] investigated two flat plate solar collectors, one equipped with an ETFE (Ethylene Tetra Flouro Ethylene) foil sandwiched between an absorber and a cover glass and the other is without ETFE foil. The efficiency of both the collectors was calculated for different mass flow rates. The yearly thermal behaviour of the collector with ETFE foil was 10% higher than the collector without ETFE foil.

L.M. Ayompe et al. [21] studied year round energy performance of the solar water heating system with flat plate collector in a temperate climate and they found annual average collector efficiency and system efficiency 45.6% and 37.8% respectively. The maximum outlet fluid temperature was 70.4 °C.

M. Khamis Mansour et al. [22] investigated thermal behaviour of a new design of minichannel-based solar flat plate collector. Arrays of minichannels are located on the absorber plate which is cover by single glass cover. The modified system was compared with the conventional flat plate collector and it was found that the heat removal factor of modified system was higher by 16.1%.

Gurveer Sandhu et al. [23] investigated thermal performance of the flat plate solar collector using insert devices such as twisted tapes, wire coils and wire mesh inserts. The impact of collector inclination was also investigated. And they concluded that the performance of the concentric coil perform best in wire coil family, whereas twisted tapes with small pitch ratio perform best in twisted tapes family and collector inclination doesn't have any significant impact.

Sanjay Yadav et al. [24] did analysis of solar air heater duct having protrusions on absorber plate as roughness elements and developed nussult no. and friction factor correlation. In this experiment the roughened wall of duct was uniformly heated while other three walls were kept insulated. The maximum heat transfer augmentation in roughened duct was 2.89 times higher than the smooth duct; and the friction factor was 2.93 times as compared with sooth duct.

Zhenqian Chen et al. [25] analyse energy storage process of flat plate solar collector with aluminium porous foam with paraffin the phase change material. And they concluded that the using of aluminium foam in the paraffin has significant effect on heat transfer rate and melting rate of paraffin. Heat transfer performance of a flat plate solar collector was improved by using aluminium porous foam with paraffin.

A. H. Abdullah et al. [26] evaluated thermal performance of flat plate solar collector which was equipped with rectangular-cell honeycomb. Rectangular cell honeycomb materials were placed in between the absorber plate and the glass cover of solar collector to suppress the convection heat losses. And investigated the effect of air gap thickness on top of and under the honeycomb materials and they found that the arrangement of honeycomb with bottom air gap thickness of 4mm was most advantageous as it offer the lowest heat loss coefficient.

III. Conclusion

Based on the literature review on solar thermal collector, it is found that the many researchers have carried out an extensive experimental and numerical investigation to enhance the performance of solar thermal collector by minimizing top heat losses, proving artificial roughness, fins, inserts, and by changing geometry & materials. The change in fluid flow rate affects the efficiency of the solar thermal collector.

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