Performance Analysis of Flat Plate Solar Water Collector using Different Shapes of Riser Tubes: A Review

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Abstract - *Solar energy has grown increasingly popular as a source of household and industrial heating. One of the most extensively utilized solar applications is the flat plate collector type solar water heater. However, because to the shifting nature of the energy source, the effectiveness of currently employed fixed flat plate collectors is minimal. There has recently been a lot of research towards improving the thermal efficiency of solar flat plate collectors. This report includes a review of recent research on changes in design factors and their impact on solar thermal flat plate collector efficiency. This well-designed collector can generate hot water up to the boiling point of water, which may be utilized for a variety of home and industrial heating applications.*

Key Words: Flat plate solar collector Semi-circular tubes, Accelerated tubes, Absorber plate, Dimple riser tubes, and other shapes are available.

1. INTRODUCTION

The world's development is occurring at the expense of energy use. The world's energy needs are currently being met by traditional sources. However, traditional energy sources such as fossil fuels have two major drawbacks: For starters, their supply is limited, and they also pollute the environment. It causes people all across the world to consider other energy sources. Renewable energy sources overcome the drawbacks of traditional energy sources. However, the usage of these resources is limited due to a lack of understanding about these sources and the expensive initial cost of conversion systems. Solar energy is the most potential renewable energy resource since it is a very large, clean, unlimited, and widely available source of energy A basic flat-plate collector is made up of four parts: I the absorber plate, (ii) the tubes attached to the absorber plate, (iii) the clear cover, and (iv) the collection box. The collection plates absorb as much solar irradiation as possible and transfer the heat to the working fluid flowing through the absorber tube. The heat transfer fluid is usually passed through a metallic tube that is attached to the absorber plate. The purpose of a flat plate collector type solar water heater is to convert solar radiation into heat in order to meet energy requirements. However, because of its higher initial cost and lesser efficiency, it is not widely employed due to various restrictions. To overcome these constraints, improvements in collector design characteristics as well as modifications such as reflectors, tracking systems, or concentric collectors are required. Flat plate collectors have the advantage of utilising both the beam and diffuse components of solar energy. Flat plate collector efficiency is determined by plate temperature, ambient temperature, solar insulation, top loss coefficient, emissivity of plate, cover sheet transmittance, and number of glass covers.

Any solar energy collection system designed for operation in the low temperature range, from ambient to 60^{0}C, or the medium temperature range, from ambient to 100^{0}C, relies on the flat plate collector. A well-designed flat plate collector provides heat at a reasonable cost over a lengthy period of time. Flat plate collectors are often made up of arrays of circular cross-sectional tubes bonded to the absorber plate to transmit heat from the absorber tube to the working fluid. [1].

II. LITERATURE SURVEY

The papers discuss the design, analysis, and performance of flat plate collectors with various riser tube designs. The influence of a variety of riser tube layouts on the efficiency of flat plate collectors is investigated.

Sunil K. Amrutkar et al. [1], Figure 1 depicts a small sample of the vast array of flat plate solar collectors now in use. Diagrams A (1, 2) depict traditional liquid warmers with tubes soldered or otherwise affixed to the upper or lower surfaces of metal sheets in this diagram.

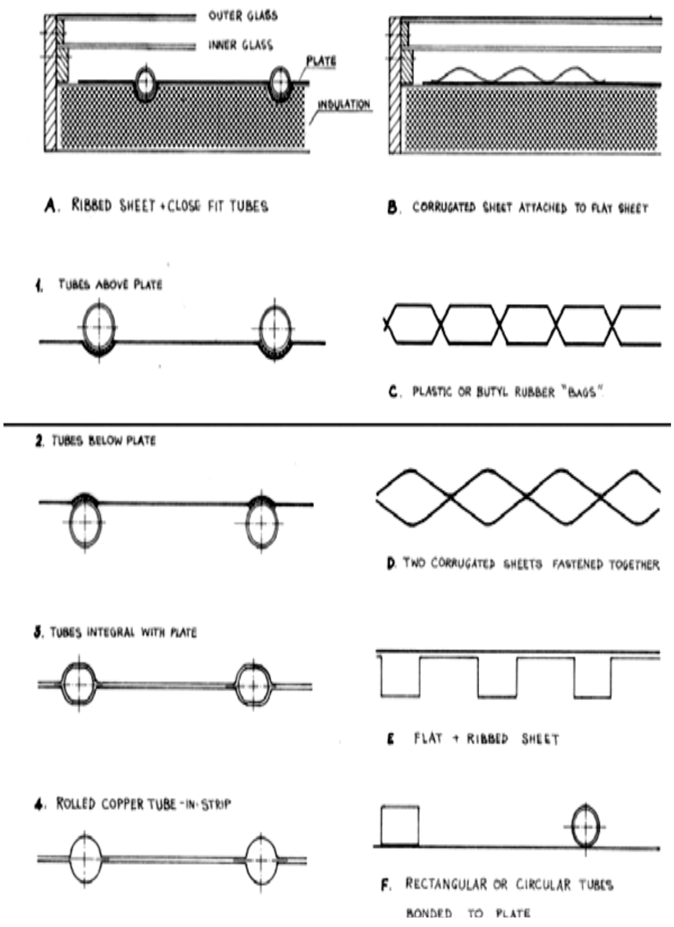

Figure 1: Absorber Plate and Tubes Bonding Sections [1]

A bonded sheet design in which the tubes are integrated with the sheet ensures a good thermal connection between the absorber plate and the tubes, as shown in Diagram A3. Diagrams B and D show several methods of joining galvanised steel sheets to create watertight containers with independent fluid passageways. Diagram C depicts the notion of employing parallel sheets of copper, aluminium, or galvanised steel that are dimpled and welded or riveted together at intervals. The usage of tubing with a rectangular or circular cross-section bonded to the plate is demonstrated in diagram F; the rectangular cross-section allows for better contact between the tube and the plate. The actual assembly might be done by mechanical pressure, thermal cement, or brazing.

BalaramKundu et al [2], The result indicates as shown in Figure 3 that there is optimum fin efficiency of trapezoidal profile for constant plate volume. The RPSLT profile of absorber plate is superior to other profiles because of higher performance and less difficulties in fabrication. As shown in Figure 2, a comparative research was conducted on the performance and optimization of many profile forms, including rectangular, trapezoidal, and rectangular profile with a step change in local thickness (RPSLT).

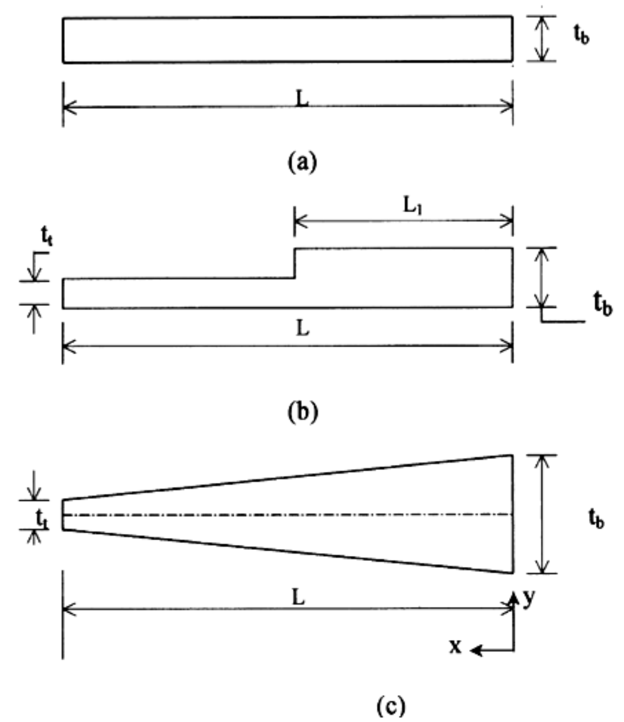

Figure 2: Schematic Geometry of a Symmetric Heat Transfer Element.

a) Rectangular Profile, b) RPSLT, C) Trapezoidal Profile [2]

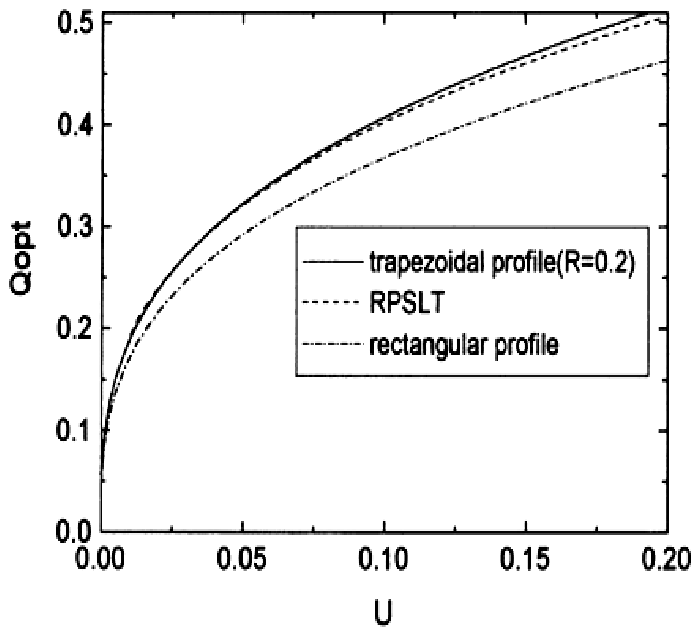

Figure 3: The Maximum Energy Transfer Rate by Different Profile as a Function of Plate Volume U [2]

K.E. Amori et al. [3], examined the performance of two identical solar water heaters made locally. One of the collectors has a novel accelerated absorber design, with risers composed of converging ducts with exit areas half as large as the entrance. The other collector was a traditional absorber with risers that were all the same cross sectional area.

From January to April 2009, they tested the two solar water heaters for various water withdrawal profiles, including continuous, interrupted, and no load, as well as horizontal and vertical storage tank orientations.

The researchers looked into two types of storage tanks: those with two concentric cylinders and those with helically-coiled tubes in the cylinder. The novel design achieved a significant improvement in thermal performance (about 60%) of absorbed heat (useful gain) at solar noon when compared to the conventional kind, according to the results. At solar noon, the accelerated absorbed flat plate had an instantaneous efficiency of 31.5 percent, whereas the traditional absorber had an instantaneous efficiency of 30.5 percent (16.5 percent). The accelerated absorber's risers had higher longitudinal water temperature changes than the normal absorbers.

Basavanna S et al. [4], Instead of a circular tube, a triangular tube has been investigated. Due to better contact between tube and plate, the exit temperature rises with the triangular tube. The collecting fluid gains heat and its temperature rise as the fluid runs through the tube. Because this arrangement tube has larger surface area of contact between the tube and the plate, the temperature at the end section of the absorber plate is high, resulting in increased heat absorption and hence improved collector performance. Around the world, a lot of work has gone into the design and improvement of solar thermal flat plate collectors. However, there is stilll a significant opportunity to enhance the thermal efficiency of flat plate collectors.

Jae-Mo Koo et al. [5], has concentrated on the various aspects that influence the riser and header tube configuration. The heat transfer fluid is conducted or directed from the inlet header to the outlet via riser tubes or fins. The choice of materials, inner and outer diameters, volumetric flow rate (m), inlet pressure, number of tubes, tube spacing, and the thermal conductivity of the link between tube and absorber sheet must all be carefully considered when designing. For tube and plate designs, good thermal bonding, such as a braze, weld, or high-temperature solder, are necessary to provide good heat transfer from the absorbent surface into the fluid, as shown in figure 4.

The tube-to-tube distance reduces as the number of tubes increases, and the collector heat removal factor FR rises. As a result, as the number of tubes increases, the instantaneous efficiency improves. Figure 9 depicts the effect of the number of tbes on the collector's immediate efficiency. The degree of improvement diminishes, and the number of tubes required for the collector is determined by the production cost. The instantaneous efficiency of 11 tubes is nearly comparable to that of 10 tubes, aas demonstrated in this graph [5].

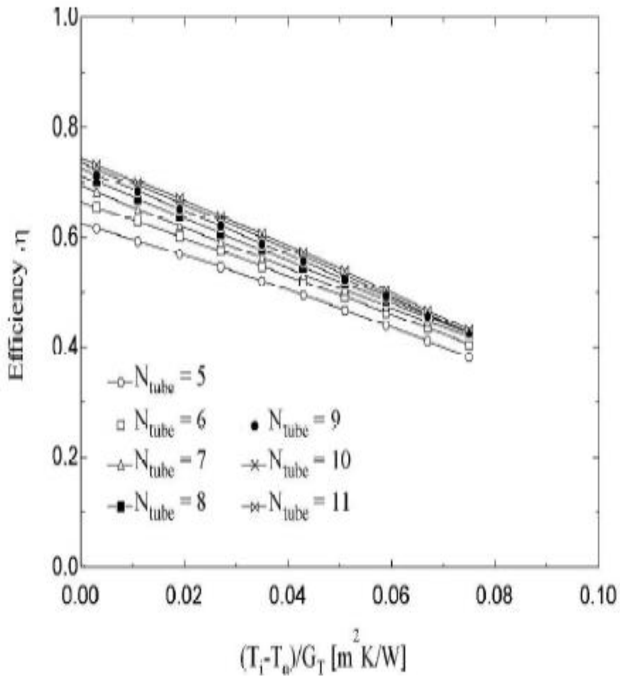

Figure 4: Effect of number of tubes on efficiency [5]

Vipin.B.Nanhe et al. [6], when a semicircular type tube is used to blow to the absorber plate, the area of intimate contact between the fluid and the absorber plae rises, and the adhesive resistance reduces. Additionally, the use of a flat plate collector with a trapezoidal form and a four-sided mirror provided improved solar heat collection, a better match of solar collection to load needs, and acceptable efficiencies at higher working temperatures. As a result, the solar flat plate collector's performance has improved. The performance of two locally made comparable flat plate solar collectors is compared in this study. One of these collectors is a new type of accelerated absorber with converging duct risers (the exit area is half that at the entrance). The other collector is a traditional absorber collector (its risers have the same cross sectional area along its length). In compared to the conventional type, the nnew design achieves a significant increase in thermal performance of roughly (60 percent) of absorbed heat (useful gain) during solar noon

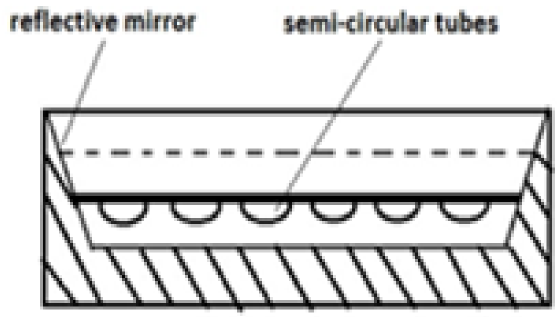

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Figure 5: Trapezoidal flat plate collector with semicircular tubes [6]

R. B. Manoram et al. [7], Using a heat transer enhancer in the tube is seen to be one of the most effective ways to improve the system's thermal efficiency. Dimples are used as a heat transfer enhancer in this paper and are manufactured using a punching machine. The study investigates the impact of dimples and their various characteristics on the solar collector's thermal efficiency and friction factor numerically. Pitch-to-dimple diameter ratio (P/Dd), number of dimples, and mass flow rate are all varied in the simulation. When compared to a typical tube, the friction factor due to the presence of dimples increased by 11.1 percent. The presence of dimples enhances the dissipation of dynamic pressure into the fluid particles, resulting in an increase in friction factor. Dimples are a superb heat transfer enhancer because they improve thermal efficiency while reducing friction. At 2.5 kg min 1, a maximum increase in collector efficiency of 32.3 percent was observed for P/Dd ratio 3 with six dimples. Increased surface area and disturbances of fluid partiicles at the boundary layer are responsible for the rise.

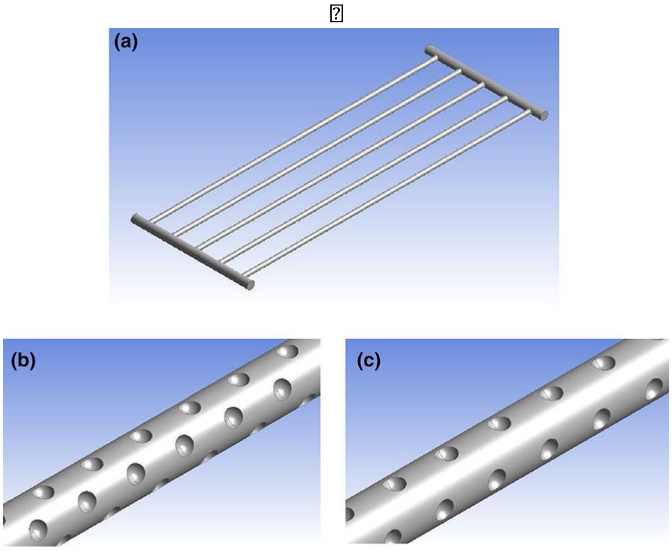

Fig. 6 **a** Model of solar collector, **b** model of dimpled tube with four dimples between two consecutive plane

c models of dimpled tube with [7]

Six dimples between two consecutive planes

III. MATERIALS FOR RISER AND HEADER TUBES

The main purpose of the riser and header tubes is to absorb as much heat energy as possible from the absorber plate and transfer it to the circulating fluid. Thermal conductivity, corrosion resistance, resistance to stagnation temperatures, durability and ease of handling, availability and cost, and the energy required to manufacture riser annd header tubes are all factors that influence the material selection. Because of its great heat conductivity, copper is the best of the widely available materials, as shown in table 1.

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Table 1: Thermal conductivity of absorber materials

Material	Thermal conductivity in W/mk
Copper	376
Aluminium	205
Mild steel	50
Stainless steel	24

IV. CONCLUSION

Based on a survey of the literature, it has been determined that research has been conducted in recent years to enhance the thermal efficiency of solar flat plate collectors A number of studies have been conducted to determine the impact of modifications iriser tube layouts on the thermal efficiency of the solar flat plate collector. However, thorough optimization of the design and operational conditions, such as mass flow rate, is still not done today. The data supplied here will be useful for future reseaearch in this field.

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