EXPERIMENTAL INVESTIGATION ON EFFECT OF MODIFIED SOLAR COLLECTOR IN SOLAR WATER HEATING SYSTEM

by

Gopal SIVARAMAN[a*], Raman MOHAN[a], and VENKATARAMAN HARIKRISHNAN[b]

[a] Department of Mechanical Engineering, Sona College of Technology, Salem, India
[b] Asian Pulp and Paper (APP), Sinar Mas Company, Indonesia

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The conventional solar water heater is always use the flat plate collector along with straight tubes for heating of water using solar rays which is having efficiency of low. This efficiency is directly linked to dimension of the flat plate collector which is critical to both cost of the equipment and also high carpet area requirement in buildings for installment. To overcome this dimensional criticality we propose to change the flat plate collectors into bend type tubes. In general increasing the surface area of the collector will increase the heat transfer capability of the solar collector and possibly its efficiency. Conventional solar water heaters have longitudinal flat surface collector tubes for reaping the benefits of solar heating. Water temperature increases 10-12 °C than existing water heater and also payback period less than the existing one.

Key words: *solar water heater, design modifications, thermal performance, heat storage*

Introduction

The literature review of solar water heaters shows that that the different type of solar water heaters have been investigated experimentally under different systems and operating conditions by several researchers [1]. A comparison of performance of these heaters become difficult without identical values of parameters such a ambient conditions, inlet water temperature, water mass-flow rate per, gap between the absorber and cover plates, intensity of solar radiation *etc.* [2, 3]. Thus to compare the performance of these heaters under identical values of parameters, their simulation becomes necessary. In view of the previous, simulation of modified solar collector has been done in the present work [4-6]. The modified solar collector selected for this purpose are single-glazing, bended 9 copper tubes connected with bottom and top header, copper absorber plate, and glass wool insulation covered by M.S frame. Water flows from storage tank to bottom header and it rises to top header and again returned to storage tank. The performance of modified solar collector will be compared with standard available solar collector.

* Corresponding author, e-mail: indsivaraman@gmail.com

Experimental set-up

The experimental set-up consists of a flat plate collector of 2 m^2 aperture area connected to a well-insulated storage tank of 120 L per day capacities and named as bended tube collector. The cold water from the storage tank enters the collector from the lower header and is evenly distributed in the nine parallel riser tubes [7]. The riser tubes are brazed to the bottom of a black absorber plate and the absorbed solar energy is conducted to the riser tubes. The heat is transferred by convection from the riser tube wall to the fluid. Finally the hot water is collected from the upper header and stored in the insulated storage tank. The temperature difference in storage tank accelerates the driving force and the cycle is repeated until the temperature difference between the inlet and outlet water is zero. The solar energy is transmitted to the absorber plate by a single transparent 3 mm thick glass cover. To minimize heat losses, the collector and the pipe connections are well insulated. The copper material for headers and fins are chosen for high heat conductivity. Glass covering improved transmitivity.

Theoretical analysis

To determine the temperatures of each glass cover, the absorber plate and the water elements that are axial flow functions, the boundary and initial conditions are required, x, and time, t. The initial conditions are for the glass cover, $T_g(x, 0) = T_{air}(0)$, for the absorber plate, $T_p(x, 0) = T_{air}(0)$ and for the water, $T_{wi}(x, 0) = T_{wo}(x, 0) = T_{air}(0)$ both for $x = 0$ and L. For the glass cover, the boundary conditions are $T_g(0, t) = T_{air}(t)$, for the absorber cylinder, $T_p(0, t) = T_{air}(t)$, and for the water, $T_{wi}(0, t) = T_{air}(t)$ for $t = 0$ to 12 hours each.

The performance of a horizontal flat plate collector may be evaluated by calculating the instantaneous efficiency [8, 9], $\eta(t)$:

$$\eta(t) = \frac{mC_{pw}[T_{w,o}(L,t) - T_{w,i}(o,t)]}{I(t)A} \tag{1}$$

Results and discussion

The temperature results were for three different days with maximum calculated irradiation of 1092 W/m^2 and 1086 W/m^2, respectively. The ambient air temperature and incident irradiation during the days of running the experiments are also shown in fig. 1. From the figures it is clear that all the measured and calculated water-outlet temperature trends are similar in that they gradually begin to rise in the morning with the increased radiation intensity, reaching a maximum in the early afternoon due to the heater's thermal capacity, and slightly decrease in the afternoon as the radiation decreases. The predicted temperature of the water outlet closely matched the corresponding experimental measurements with the best agreement with the mass-flow rate. The maximum error between the measured and computed results for the water outlet temperature was less than 7% for the conventional collector, but was about 12% in late afternoon. The corresponding maximum error for the modified type was about 10%, but less than 12%.

Figure 1. Modified solar water heater

The radiation of day's starts from 6 a. m. and ends with 6 p. m.; the different radiation with corresponding time for two days is shown in fig. 2. The figures clearly show that the insolation is increasing with time till 12 noon later it became decreasing trend. This is due to the sun position corresponding to Earth's surface. The glass temperature is almost same for the both existing and modified collectors, it also nearest to the values of ambient temperature because of less thermal conductivity of glass and convection loss due to the wind velocity.

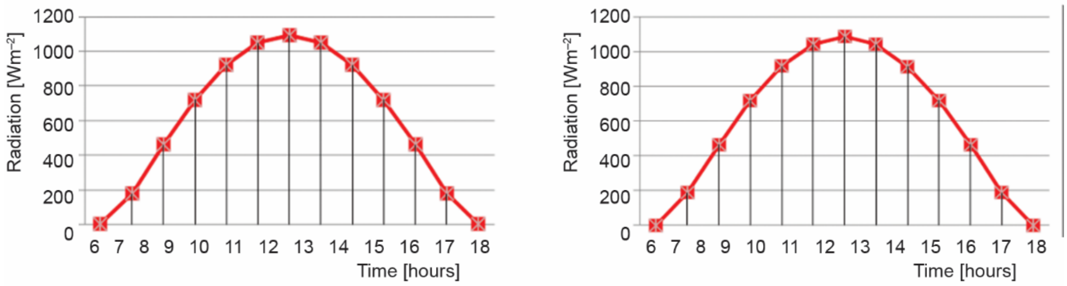

Figure 2. Solar insolation *vs.* time

The maximum difference of plate temperature is up to 5 °C for existing and modified collectors this is due to more energy gain in modified collector; the thermal loss from the modified collector is less compared to existing one. As for the temperature of the absorber plate of both types, similar trends and behavior were observed throughout the day, although the increase in the absorber temperature of the modified type was more substantial than that of the existing type around midday. The observed behavior of these temperatures could be accounted for by the larger thermal capacity of the absorber, it also took a longer time to cool in the late hours of the afternoon and evening. The largest deference's in temperature were seen at mid of day.

The comparison of temperature is shown in fig. 3, for variation of water outlet temperature with day time. First, considering the temperature of the water outlet, it can be seen that the temperatures of both types begin nearly the same in the early morning hours and begin to rise with increased irradiation. As the time approached mid-day, slightly higher measured temperatures of the modified type maximum difference is 12 °C are observed. However, as the day proceeded, the temperatures of both types decreased gradually until after 4 pm where the temperature of the existing type began to drop below that of the modified type (between 3% and 9%).

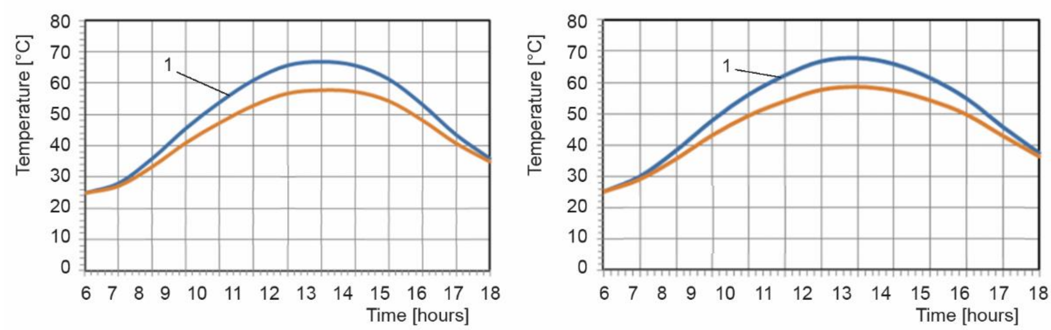

Figure 3. Comparison of water outlet temperatures *vs.* time; *1 – m-water out temperature*

Figure 4 shows Instant efficiency variation for existing and modified bend tube type collectors with time. The system and the theoretical efficiency values estimated for different days using eq. (1) were included in fig. 4. It is observed that the instantaneous efficiency were within the range of 50-90% and were higher for the modified type around full day. In general, the agreement of efficiency, for both types was pronounced mostly with the daily averaged efficiency which reached about 65%. The temperature of ambient air, glass, and plate for both days is shown in fig. 5.

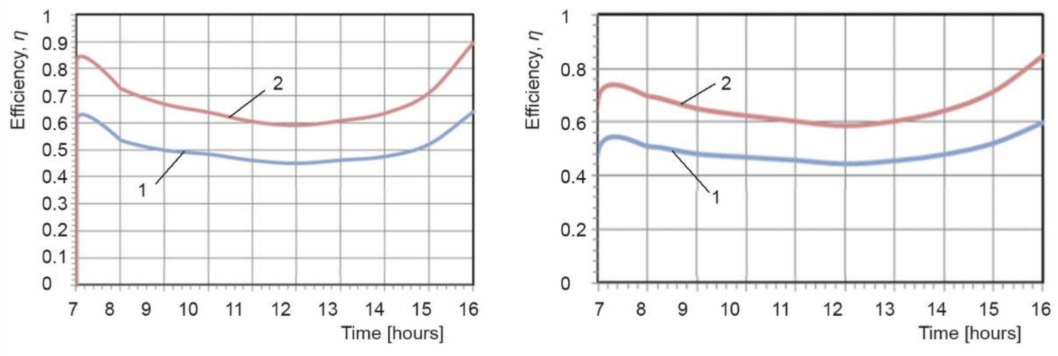

Figure 4. Instant efficiency *vs.* time; *1 – e-efficiency, 2 – m-efficiency*

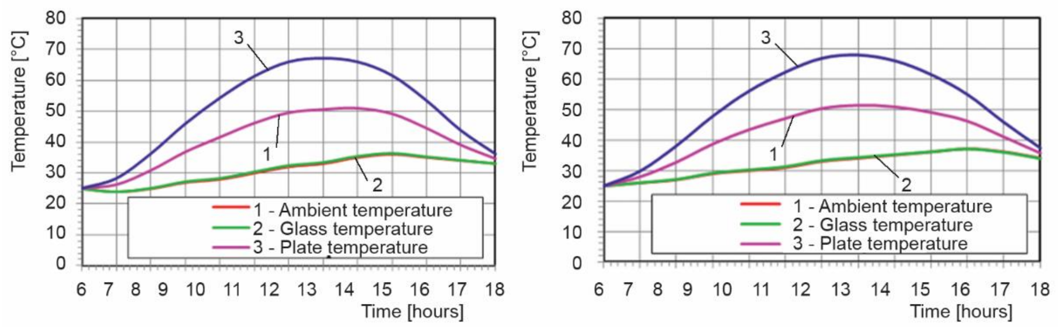

Figure 5. Temperature of ambient air, glass, and plate *vs.* time

Payback period

The initial investment cost of solar water heaters is much higher than that of electrical heaters but it reduces the energy bill of customer, the copper plate and copper tubes increases the rate of solar water heating system much higher. For modified collector the cost involved is Rs. 25000 (1 Rs = 0,014 $). Payback period for the modified set-up is estimated as 987 days.

Conclusion

Following conclusions can be drawn for the present work:

- The modified bend tube collector has more efficient than that of the existing one available in market.

- The bend tube collector utilizes more energy than the existing one and it increases the outlet water temperature 10 °C to 12 °C more than the existing collector.
- The payback period is also less than existing one.
- The heating surface area of modified collector is more the existing one so the energy utilization from the Sun is much higher. However it is more costly than the existing one. In future, surface of the collector tube will be nanocoated and it will be tested in solar water heater to measure the heat transfer rate.
- The obtained heat transfer rate will be compared with existing flat plate collector.

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