The Effect of Specifications Flat Plate Collector on its Performance

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ABSTRACT

The present paper includes a theoretical study concerning the effect of specifications for absorber flat plate collector (collector plate temperature, outlet temperature, storage volume and the collector area) on its performance, also its effected on flow rate of fluid and the efficiency of flat plate collector. The present data have been compared with other studies.

تأثير خصائص اللوح الماص على اداءه

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الملخص

تضمن البحث دراسة نظرية حول تأثير مواصفات اللوح الماص لمجمع شمسي (درجة حرارة اللوح الجامع ، درجة الحرارة النهائية ، حجم الخزان ، ومساحة اللوح) على اداءه ومدى التأثير على تدفق السائل وكفاءة السخان الشمسي. تمت مقارنة النتائج المستحصلة مع بحوث اخرى.

I. INTRODUCTION

The solar collector is the essential item of equipment which transforms solar radiant energy to some other useful energy form. The rate at which energy is collected by a solar heating system can be increased by increasing the flow rate through the collectors.

The problem of optimal control of flow rate through the collector was formulated under simplifying assumptions and conditions of an optimal control of the system have been studied by (Kovarik & Lesse, 1976). Winn and Hull presented an approximate analytic solution between solar power and fluid moving power (Winn & Hull, 1979). The optimal flat plate collector fluid flow rate was determined for several system models, in addition, the dependence of the collector efficiency factor on flow rate is considered and its effect on the optimal control was determined by (Winn R. & Winn C., 1981). The function of the optimum mass flow rate through the collector were investigated by (Kerim Kar, 1985) and (Kerim Kar & Shaahid, 1989).

This study takes into consideration the effect of specifications for flat-plate collector (collector plate temperature , outlet temperature, storage volume and the collector area) to the variable β (ratio between volume flow rate ($\dot{m}$) and plat-outlet temperature difference (T_p-T_o)), also its effected on flow rate of fluid and the efficiency of flat plate collector.

II. THE COLLECTION EFFICIENCY

An efficient panel is one that enhances heat transfer to the fluid and minimizes the transfer to the collector surrounding. A measure of flat plate collector performance is the collector efficiency (η) which is defined as (Sol Wieder, 1982) :

$$\eta = \frac{\rho C \dot{m}(t) \Delta T}{A \int I_N(t)\, dt} \qquad \ldots(1)$$

where

ρ = water density = 1 gm/cm^3

C = the specific heat of water = 1 cal/gm.C° ,

$\dot{m}(t)$ = the volume flow rate of the water circulation between the collector and the tank as a function of time (t) = cm^3/sec,

ΔT = outlet / inlet temperature difference,

A = collector area (cm^2)

I_N (t) = the normal insolation on flat plate collector.

The useful energy gain (Q) depends strongly on the energy losses from the top surface of the collector :

$$Q = A\,(I_N(t) - FHL\,(T_p)) \qquad \ldots(2)$$

Where FHL(T_p) is the front window heat loss. Which is lost through the glass cover and the collector plate temperature (T_p) which is given by this relation for different values of ambient temperature (T_a) and emissivity (e) (Nables & Fatma, 1993) :

$$FHL = a_o + a_1 T_p + a_2 T_p^2 + a_3 T_p^3 + a_4 T_p^4 \qquad \ldots(3)$$

Where a_o – a_4 are constant coefficients depending upon different values of (e) and (T_a).

III. CALCULATION and RESULTS

The model which is considered here consists of a single glazing solar collector panel of area (A) which is connected with wide pipings to spherical storage tank of volume (V). The rear of the collector panel as well as the storage tank are covered by an insulator of thickness (χ) and thermal conductivity (k). the collector panel faces the south and tilted at 45° with the horizontal (Abullah, et al., 1989). No water extraction is assumed during the heating period.

Due to the aborption of solar radiation, the plate inside, the collector is heated up to temperature (T_p), and the heat will transferred through the upper piping to the tank rising its temperature to (T_o).

The values of (T_p) and (T_o) are obtained from these relations (Nables, 1994) :

$$T_o = \exp^{-N} \{\int_0^t \exp^N [\frac{\dot{m}}{V} T_p + \frac{\alpha}{\rho C}(\frac{4.8}{V^{1/3}} + \frac{A}{V}) T_a] dt + T_a \} \qquad \ldots(4)$$

$$T_p = T_o + [\frac{A}{\rho C \beta}(I_N(t) - FHL(T_p))]^{2/3} \qquad \ldots(5)$$

Where

$$N = [\frac{m}{V} + \frac{\alpha}{\rho C}(\frac{4.8}{V^{1/3}} + \frac{A}{V}) t]$$

$$I_N(t) = I_o \cos\theta(t) \qquad ..(6)$$

and

I_o = constant insolation on a plate normal to the light rays = 178×10^{-4} cal/cm^2.sec,
$\cos\theta(t)$ = obliquity factor which is a function of time (t),
$\alpha = K/\chi$, (= 0.6×10^{-4} cal / sec.cm^2.C°) (Fatma, 1996),
m = total volume of discharge water from the panel (cm^3) which can be calculated from :

$$m(t_i) = \int \dot{m}\, dt = m(t_i - 1) + \dot{m}(t_i - 1)\,\Delta t \qquad \ldots(7)$$

where

Δt = the interval time = 100sec,

t = exposure time,

β = variable which is defined as the ratio of flow rate of the water inside the collector and the temperature deference ($T_p - T_o$) , (i.e) :

$$\dot{m} = \beta \sqrt{T_p - T_o} \qquad \ldots(8)$$

The solutions of (T_o), (T_p) , (FHL), … are outlined by flow diagram of the computer programme which can be shown in Fig. (1). The repetition of the previous calculation with a fixed value of β (=10), T_a (=20°C) , e (=1) and different values of panel area (A) for a chosen storage volume (V = 20000cm^3) have been taken into consideration. This is done to complete optimum value of $V\Delta T^2/A$ to obtain optimum design area (A_{op}) (Nables, 1994), and at A_{op} the T_o, T_p, $\dot{m}$ and η are also recorded.

It is worth considering that the whole previous process is repeated for different storage volumes. Then, β is changed and the same calculation is repeated until obtaining the best value of (β).

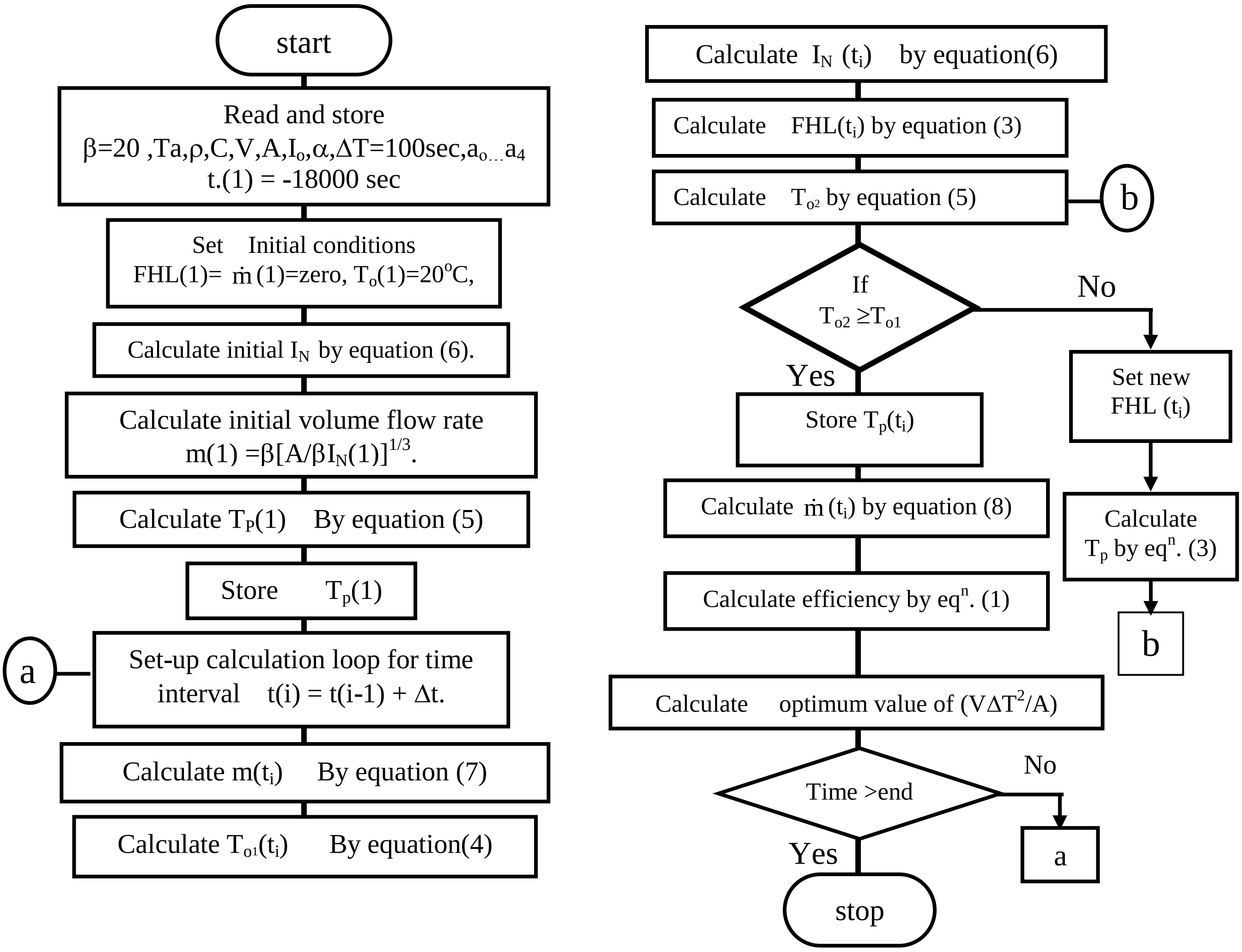

Fig. (1) Flow chart of computer programme

VI. DISCUSSION

The behavior of a solar energy collector has been studied for given constants taken from (Nables & Fatma, 1993) and (Nables, 1994).

Fig. (2) shows the effect of plate-outlet temperature difference ($T_p - T_o$) on the variable (β) and flow rate ($\dot{m}$). From this figure it can be shown that when the difference in temperature decrease the variable β will increase and this will effect on flow rate which also increase and vice versa. This means that for high flow rate the difference in plate and outlet temperature is small because there isn't enough time for T_p to increase and T_o will be close to T_p.

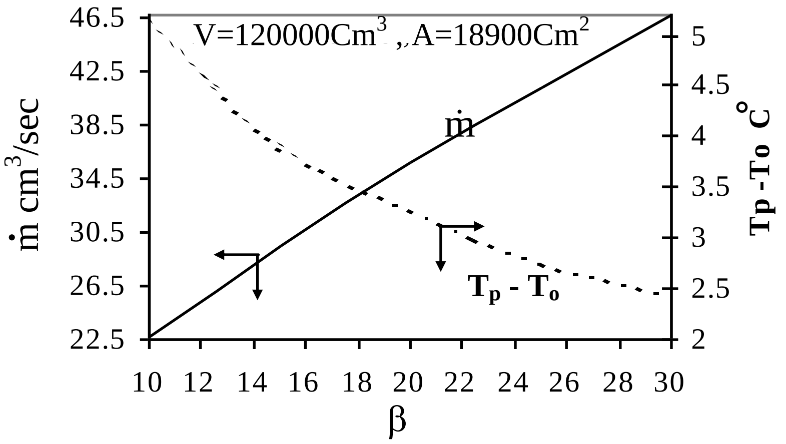

Fig. (2) The Relationship between Plate – Outlet Temperature Difference and Flow Rate with β

Fig. (3) shows when flow rate increase this will lead to decrease in plate temperature but the efficiency still increase and vice versa. This effect has been shown by different scholars (Youssef & Sakr, 1978).

Fig. (4) shows the variation of flow rate during a day for different values of (β).

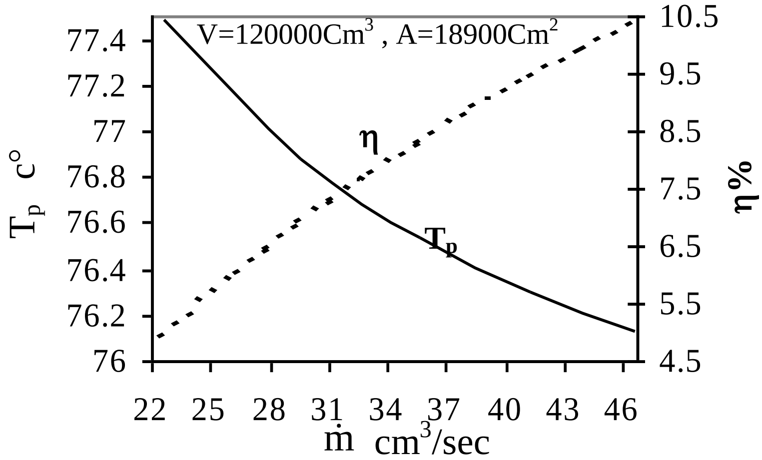

Fig. (3) Variation of Plate Temperature (T_p) and Efficiency (η) with Flow Rate ($\dot{m}$)

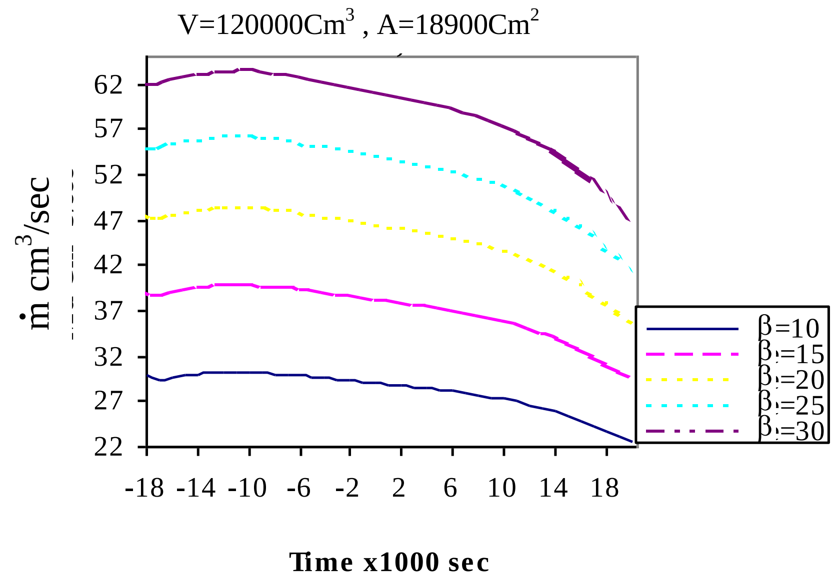

Fig. (4) Variation of $\dot{m}$ during a Day for Different Values of β

Finally, for a fixed values of storage volume (V = 120 000cm^3), panel area (A = 18900 cm^2) and β = 15, Fig. (5) shows the variation of flow rate and outlet temperature during a day. This shows the large flow rate effect on the temperature to be low.

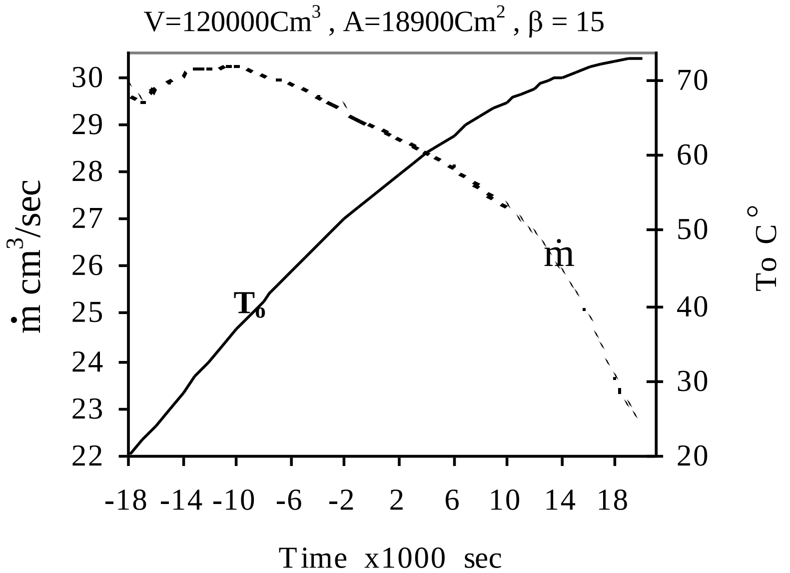

Fig. (5) Variation of Flow Rate ($\dot{m}$) and Outlet Temperature (T_o) during a Day

V. CONCLUSION

The effect of specifications for flat plate collector to the variable β has been studied. Also, it has been noticed that how flow rate and efficiency of the collector would change with different value of variable β.

It has been concluded that for various values of β (=10, …,30) flow rate of fluid will increase by increasing β (Fig. (4)). But, Fig. (3) shows that the plate temperature is slightly various by changing β from value (=20) taken by a previous attempt (Nables, 1994).

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