Collector Efficiency of the Double-Pass Solar Air Collectors with Fins

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Abstract:- The experimental study on a forced-convective double-pass solar air collector with fins in the second channel has been conducted. The experiments were conducted by changing the parameters that influence the thermal efficiency of the collector. The efficiency of the solar collectors has been examined by changing the intensity of solar radiation and the mass flow rate. The results of this study suggest firstly, the double-pass solar collector with finned absorber has efficiency of more than 75% at a mass flow rate 0.072 kg/s and solar radiation at 788 W/m^2, and this study shown that finned absorber is 8 % more efficient than flat plate absorber. Secondly, the efficiency of solar collector is significant depending on the mass flow rate and solar radiation. The efficiency is increased proportional to mass flow rate and solar radiation. At the solar radiation at 423W/m^2 to 788W/m^2 increase efficiency is about 20-30%. At a mass flow rate varies from 0.04 kg/s to 0.083 kg/s, the efficiency increase is about 35% - 50%.

Key-Words: - Collector efficiency, Double-pass solar air collector, Fins absorbers

1 Introduction

Various types of solar energy systems for agricultural and marine products have been reviewed [1]. One of the most important components of a solar energy system is the solar collector. Various applications of the solar air collector are well documented [2]. Solar collectors can be used for drying, space heating, solar desalination, etc. Conventional solar air collectors have inherent disadvantages is lower thermal efficiency. Ekechukwu and Norton [3] reviews have shown typical conventional style solar air collector to have efficiencies between 40-50%.

Various designs of solar air collectors have been proposed including multi-pass collectors. Wijeysundera et al. [4] have studied the thermal performance of two-pass solar air heaters with single and double glazing. They concluded that two-pass designs perform better than the single-pass air heaters. Choudhury et al. [5] reported their results were found that the performance of double pass air heater with a single cover is found to be most cost-effective, as compared to the other design. As well, Choudhury et al. [6] studied theoretical models for triple pass solar air heaters with single and double cover. The performances of these air heaters are compared with those of single pass air heaters with no cover, single and double covers and two pass air heaters with single and double covers. Ho et al. [7] theoretically and experimentally investigates a device for inserting an absorbing plate into the double-pass channel in a flat-plate solar air heater with recycle. As well, Ho et al. [8] studied on improvement in device performance of multi-pass solar air heaters with external recycle has been carried out under countercurrent-flow operations. Fudholi et al [9] concluded that multi-pass solar air collectors with heat transfer surface enhancement to have efficiencies between 60-70%.

The use of double-pass solar air collector with heat transfer surface enhancement has better performance than the conventional single-pass collector. Mohamad [10] has been analyzed thermal efficiency of the double-pass solar air collector with porous media, showed that the thermal efficiency can be improved by 18% compared to the conventional solar collector. Sopian et al. [11] studied the effects of changes in upper and lower channel depth on the thermal efficiency with and without porous media of the double-pass solar air collector for various operation conditions. They concluded that typical thermal efficiency of the double-pass solar air collector with porous media is about 60-70%. Karim and Hawlader [12] determined that the v-corrugated collector was the most efficient collector and the flat plate collector the least efficient. It results showed that the V-corrugated absorber plate is 10-15 and 5-11% more efficient in single pass and double pass modes, respectively.

Ali [13] studied the thermal performances of the offset rectangular plate fins absorber plates with various glazing. He was found that optimum conditions of collectors were cited to perform up to 75% thermally efficient. Naphon [14] published the mathematical model for predicting the heat transfer characteristics, the performance, and entropy generation of the double-pass solar air heater with longitudinal fins. In the present study, the main concern is to study experimentally on the efficiency of the double-pass solar air collector with fins.

2 Material and Methodology

Fig. 1 shows the cross section of the collector with the aluminium plate fins. The collector consists of the glass cover, the insulated container and the black painted aluminium absorber. The size of the collector is 120 cm wide and 240 cm long. In this type of collector, the air initially enters through the first channel formed by the glass covering the absorber plate and then through the second channel formed by the back plate and the finned absorber plate.

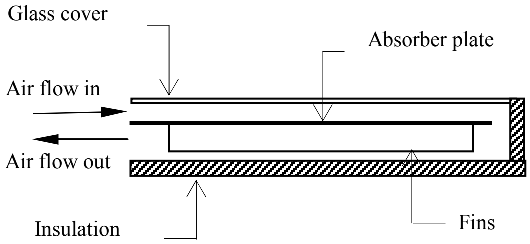

Fig.1 The schematic of a double-pass solar collector with fins absorber in the second channel

Fig. 2 shows the absorbers of the collector with different number of fins. Type I have number of fins is 126 and area of 1.512 m^2. The size of the fins is 6 cm wide and 20 cm long. Type II have number of fins is 11 and area of 1.551 m^2. The size of the fins is 6 cm wide and 235 cm long.

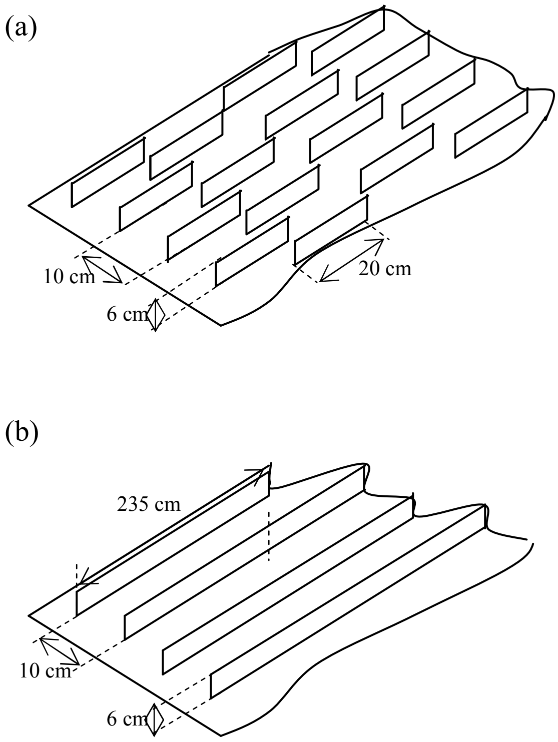

Fig. 2 Top view of finned absorbers; (a) type I, (b) type II

Fig. 3 shows the schematic of the indoor testing facility and the experimental setup of the double-pass solar collector. The simulator uses 45 halogen lamps, each with rated power of 500 W. The maximum average radiation of 788 W/m^2 can be reached. Dimmers are used to control the amount of radiation that the test collector received. A Data acquisition recorder is used to record the required parameters such as the temperatures (inlet, outlet, absorber, glass cover, and ambient) and intensity of the solar simulator. A type-T thermocouple is used in this experiment. A pyranometer is used to measure the solar intensities. This system is a forced air convection solar collector, so a blower is needed to force the air. The amount of air delivered by the blower is controlled by rheostat. A vane anemometer probe is used to measure linear velocity of air flow. The lighting control of the simulator has been adjusted to obtain the required radiation levels. The solar collector has been operated at varying inlet temperature, air flow rate, and radiation conditions. Air is circulated for thirty minutes prior to the period in which data are taken. Data include radiation, and temperatures (inlet, end of the first pass, outlet, room, glass cover, absorber plate, and back-plate).

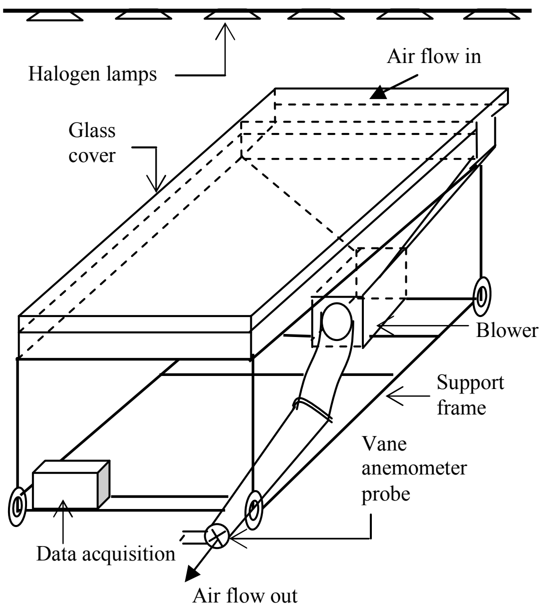

Fig. 3 Test facility of solar air collector

3 Results and Discussion

The useful gain by the solar collector to solar radiation with measured values of fluid inlet (T_i) and outlet temperature (T_o) and the fluid mass flow rate (m) is given as follows

$$Q_u = mC_p(T_o - T_i) \quad (1)$$

where C_p is the specific heat of the fluid. The physical properties of air are assumed to vary linearly with temperature (°C) by Ong [15]

specific heat

$$C_p = 1.0057 + 0.000066(T - 27) \qquad (2)$$

density

$$\rho = 1.1774 - 0.00359(T - 27) \qquad (3)$$

The efficiency of the collector is given by

$$\eta = \frac{Q_u}{A_c S} \qquad (4)$$

$$\eta = F_R(\tau\alpha) - F_R U_L \frac{(T_i - T_a)}{S} \qquad (5)$$

$$\eta = F_o(\tau\alpha) - F_o U_L \frac{(T_o - T_a)}{S} \qquad (6)$$

where A_c is the area of collector, S is the solar radiation incident on the collector, F_R is heat removal factor referred to inlet temperature of solar collector, F_o is heat removal factor referred to outlet temperature of solar collector and U_L is collector total loss coefficient.

Fig. 3 shows the variation of temperature with experiment time is about 75 minutes for solar radiation of 788 W/m^2 and mass flow rate at 0.039 kg/s. Generally, temperatures increased constantly up to 60 minutes and then tended to approach a constant value.

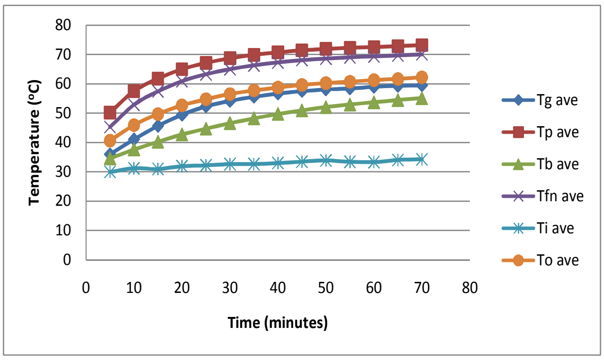

Fig. 3 Temperatures data

The effect of solar radiation on the efficiency for type I absorber is shown in Fig. 4 and 5. At the solar radiation at 423W/m^2 to 788W/m^2 increase efficiency is about 20-25%. Fig 5 shows the effect mass of flow rate on the efficiency of the double-pass solar air collector type I absorber. The efficiency of the collector is strongly dependent on the flow rate. The collector efficiencies increase with flow rate, efficiency increase is about 40% at mass flow rate of 0.04 kg/s to of 0.084 kg/s.

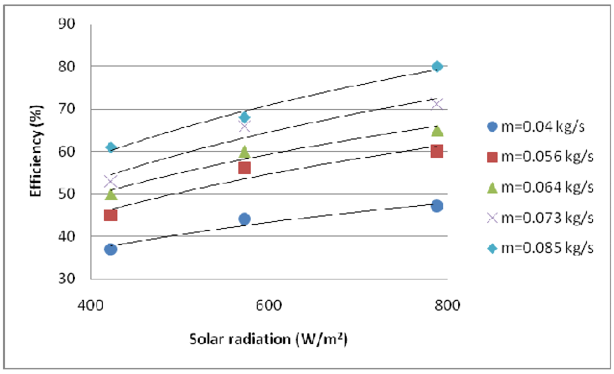

Fig. 4 The effect of solar radiation on efficiency at different mass flow rate for type I absorber

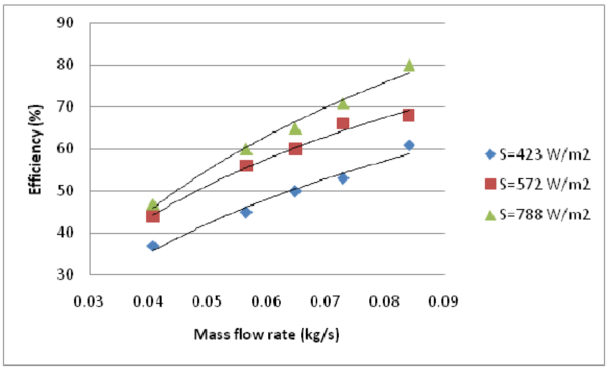

Fig. 5 The effect of solar radiation and mass flow rate on efficiency for type I absorber

Fig. 6 and 7 shows the effect of solar radiation on the efficiency for type II absorber. The increase efficiency is about 30% at the solar radiation of 423W/m^2 to 788W/m^2. At a mass flow rate varies from 0.04 kg/s to 0.083 kg/s, the efficiency increase is about 45%.

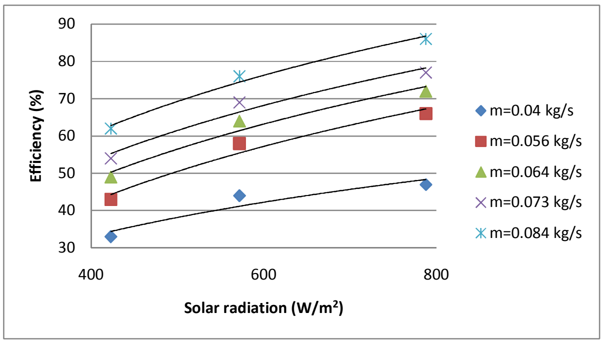

Fig. 6 The effect of solar radiation on efficiency at different mass flow rate for type II absorber

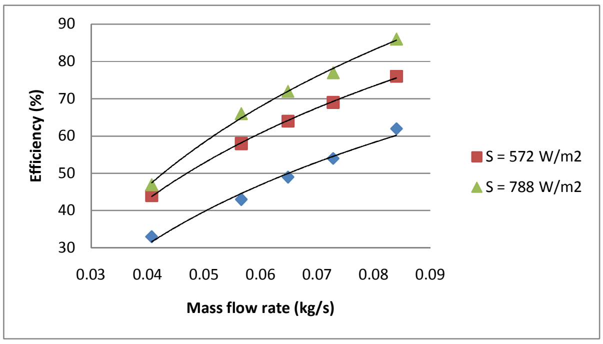

Fig. 7 The effect of solar radiation and mass flow rate on efficiency for type II absorber

To determine the physical characteristics of the collector, one represents effectiveness with efficiency curve, i.e. efficiency versus the reduced temperature parameters $(T_o-T_a)/S$ in Fig. 8 and 9. As seen in the figure shows the efficiency curve decrease with increase of the reduced temperature parameters. The curve obtained is a straight line. It will results where the slope is equal to F_oU_L and the y-intercept is equal to $F_o(\tau\alpha)$. The respective efficiency equation and the physical characteristic of the collector are presented in Table 1 and 2.

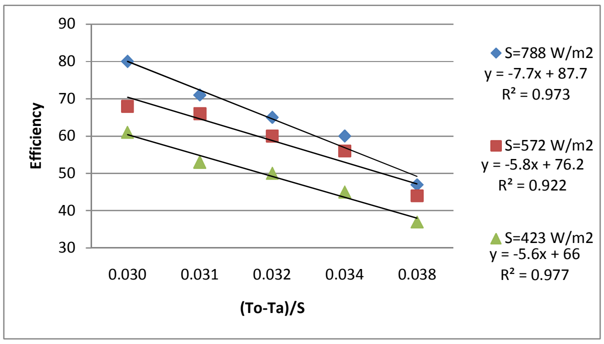

Fig. 8 Combined efficiency at different mass flow rates and solar radiations for type I absorber

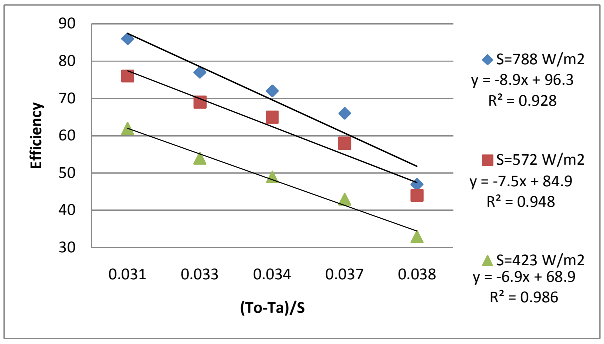

Fig. 9 Combined efficiency at different mass flow rates and solar radiations for type II absorber

Table 1 Efficiency, loss factor and efficiency equation for type I absorber

S (W/m2)	$F_o(\tau\alpha)$	F_oU_L	Efficiency equations	R^2
788	0.88	7.7	y=-7.7x + 87.7	0.97
572	0.76	5.8	y=-5.8x + 76.2	0.92
423	0.66	5.6	y=-5.6x + 66	0.98

Table 2 Efficiency, loss factor and efficiency equation for type II absorber

S (W/m2)	$F_o(\tau\alpha)$	F_oU_L	Efficiency equations	R^2
788	0.96	8.9	y=-8.9x + 96.3	0.93
572	0.85	7.5	y=-7.5x + 84.9	0.95
423	0.69	6.9	y=-6.9x + 68.9	0.9

The efficiency and collector outlet temperature were an important parameter for a wide variety of applications, such as solar industrial process heat and solar drying of agricultural produce. Outlet temperature was investigated for mass flow rates from about 0.03 to 0.09 kg/s. Fig. 10 and 11 shows the optimum operating condition with respect to efficiency and outlet temperature were determined for S=788 W/m^2. The optimum efficiency (70-80%) lies between the mass flow rates 0.07-0.09 kg/s. A mass flow rate of about 0.063 kg/s is considered for solar drying of agricultural produce. Minimal increase in the efficiencies occurs as the mass flow rate is increased, therefore, operating at these conditions will only increase the blower power.

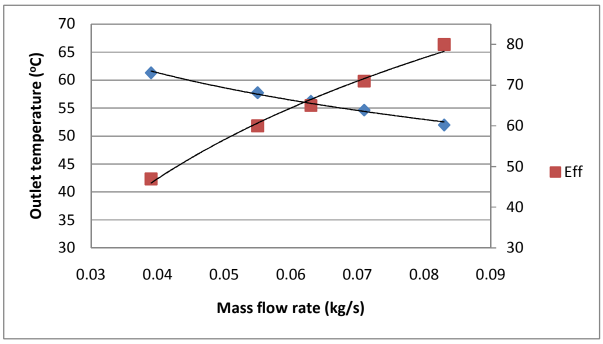

Fig. 10 Variation of T_o and η with mass flow rate at S=788 W/m^2 for type I absorber

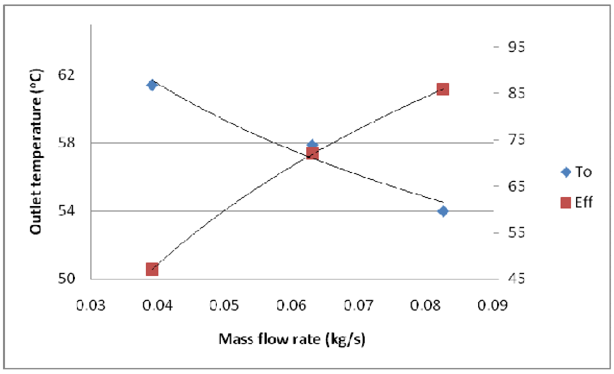

Fig. 11 Variation of T_o and η with mass flow rate at S=788 W/m^2 for type II absorber

Fig. 12-17 show the variation of increase temperature (T_o-T_i) and efficiency with mass flow rate for S=788 W/m2, S=572 W/m^2 and S=423 W/m^2, respectively. As seen in the figures, as efficiency increased with flow rate, increase temperature (T_o-T_i) decreased correspondingly

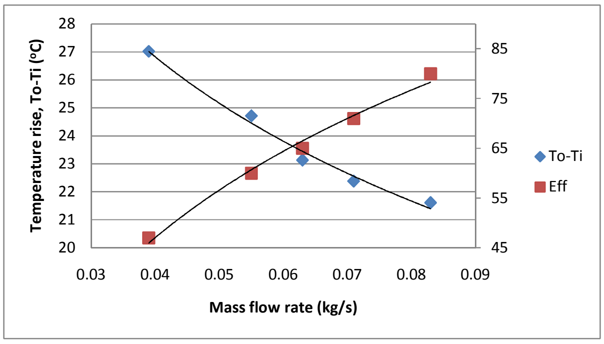

Fig. 12 Variation of T_o-T_i and η with mass flow rate at S=788 W/m^2 for type I absorber

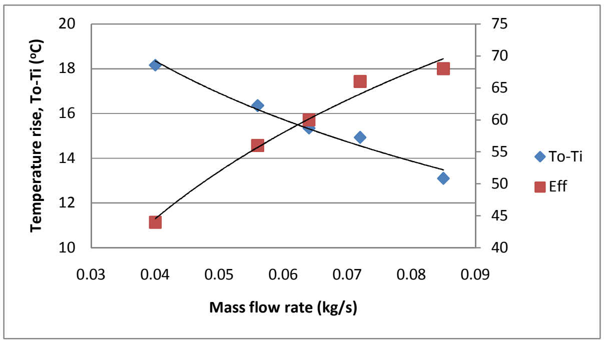

Fig. 13 Variation of T_o-T_i and η with mass flow rate at S=572 W/m^2 for type I absorber

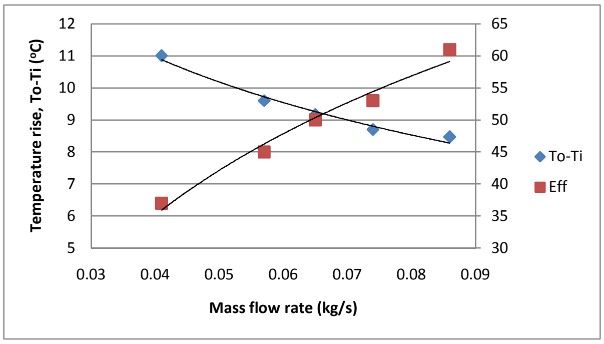

Fig. 14 Variation of T_o-T_i and η with mass flow rate at S=423 W/m^2 for type I absorber

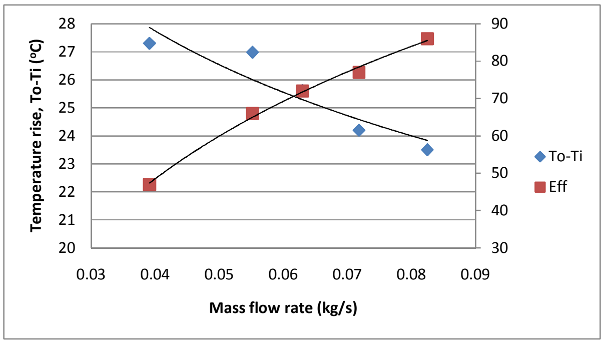

Fig. 15 Variation of T_o-T_i and η with mass flow rate at S=788 W/m^2 for type II absorber

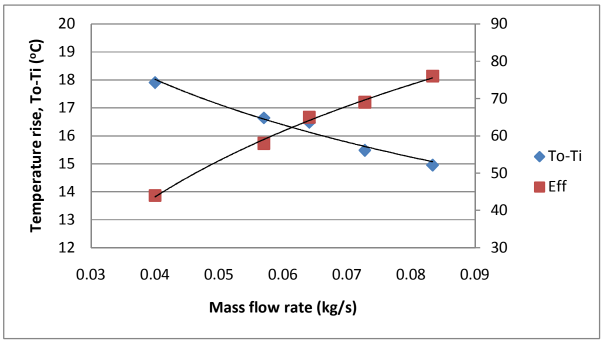

Fig. 16 Variation of T_o-T_i and η with mass flow rate at S=572 W/m^2 for type II absorber

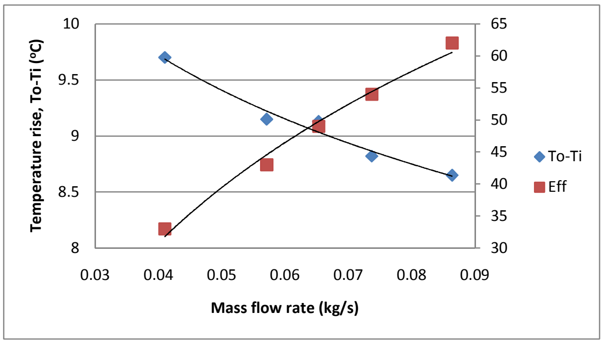

Fig. 17 Variation of T_o-T_i and η with mass flow rate at S=423 W/m^2 for type II absorber

Fig. 18 shows the variation of efficiency with mass flow rate for the flat plate, type I absorber and type II absorber. As seen in the figure shows that the type I absorber is more efficient than the flat plate, and the type II absorber is more efficient than type I absorber. This experiment study shows that the finned absorbers are 2-8% more efficient than flat plate absorber.

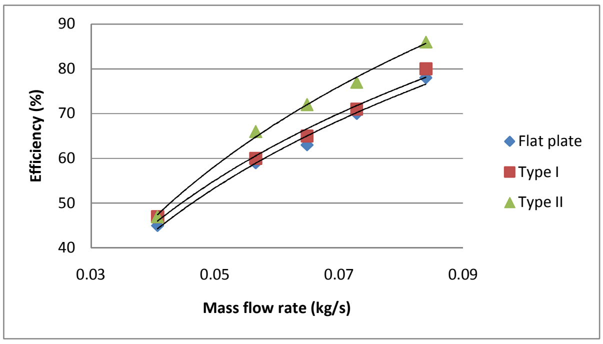

Fig. 18 Comparison of efficiency with mass flow rate of flat plate and finned absorber

4 Conclusions

Performance curves of double-pass solar air collector with finned absorber in lower channel have been obtained. These include the effects of mass flow rate and solar radiation on efficiency of the solar collector. The efficiency of the collector is strongly dependent on the flow rate. It increases with flow rate. The solar collector with finned absorber has efficiency of more than 75 % at a mass flow rate of over 0.072 kg/s. This study shown that finned absorber is 8 % more efficient than flat plate absorber.

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