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Development of Solar Air Collector with Crimped Baffles for Drying Applications

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Abstract— **In the present work, a solar air collector with crimped baffles has been developed towards obtaining a required outlet temperature of solar air collector suitable for an agricultural dryer. The solar air collector was designed and constructed and installed in the campus of Department of Thermal Engineering, Hoa Binh Xuan Loc Vocational College, Bienhoa city, Vietnam. It consists of solar air collector with internal crimped baffles and has the total collection surface area of 2 m^2, absorber plate, glass cover, fans and collector box. The experimental results show that outlet temperature of solar air colleccỏ ranges from 40 ºC to 80 ºC. The difference value of outlet temperature between the simulation and experiment is 1.5%. Besides, the effects of the number crimped baffles, ambient temperature and solar radiation on the efficient of solar air collector were also evaluated.**

***Keywords*: solar Air collectors; crimped baffle; efficiency; solar radiation**

I. INTRODUCTION

Currently, the solar air collector is widely used for agricultural drying, wood drying and other industrial applications because it has the advantage of simple structure, mounting, easy installation, without problems such as leaks, bottlenecks and freezing in the application [1,2]. In recent years, many studies of solar air collectors have been carried out, such as changing the internal structure of the receiver, increasing the roughness of the flow and creating turbulent flow to enhance heat exchange and improve the performance of the collectors. Recently, many studies have been conducted on the application of a solar air collector for agricultural drying. Karim et al. [3] presented the results of research on developing three types of solar air collectors, namely flat plate, finned and v-corrugated a solar air collector under Singapore climatic conditions for solar dryer. EI-khawajah and et al. [4] studied the solar air collector with a grid-type absorber. The results show that the maximum efficiency for type 2, 4, 6 wings of the collector is 52.0%, 64.1% and 68.9%, respectively. EI-Sawi et al. [5] presented the results of the study using a herringbone absorption plate with continuous folding for the solar air collector. They conclude that the fish bone absorption plate can increase the efficiency by 20%. Peng et al. [6] proposed a method of creating new turbulence by establishing a series of needle-shaped wings in the absorber plate. The results of the study showed that the heat exchange efficiency of different needle wings ranged from 0.5 to 0.74. Sopian and et al. [7] evaluated the thermal efficiency of two-pass solar air collectors with hollow type in the receiver. Ramani et and al. [8] presented theoretical and empirical analysis of a 2-pass solar air collector with porous materials and developed a mathematical model to analyze thermal and pressure drop properties. Ho and et al. [9] presented a theoretical study of a two-pass flat-plate receiver with wings mounted on absorbing plates. Ucar and et al. [10] reported the effect of the shape and layout of the absorption plate on heat transfer properties through exergy analysis of solar collectors. Yeh and et al. [11] conducted a theoretical analysis of the thermal efficiency of the receiver with internal shields with the effect of receiver shrinkage coefficients. Romdhane and et al. [12] compare the effect of the different barrier layout in the receiver on the efficiency of heat recovery, pressure difference and temperature increase. Zhai and et al [13] presented an experimental investigated the effect of tilt angle on performance of solar air collector. Jianjun Hu and et al. [14] found that the introduction of baffles can enhance convective heat transfer and reduce radiant heat loss, contributing to improved performance.

This paper presents the development of a forced-ventilated solar air collector with crimped baffles. The solar air collector was designed by our research team for the purpose of agricultural product drying in temperature ranges from 50 °C to 70 °C. The effect of parameters on the efficiency of solar air collector such as the number of longitudinal wings, the thickness of the wings, the ratio between the length of the bow and the wavelength of the wing, as well as the air flow through the collector were evaluated.

II. THE MATHEMATICAL MODEL

Many researchers have performed analytical studies of solar air collector. The energy balance equation of a solar air collector is defined as follows:

$$I_t R_b A_c = Q_U + Q_L + Q_S \quad (1)$$

Where,

H is radiation energy sent per unit area of horizontal surface (W / m^2) and R_b is conversion factor from the horizontal plane to the inclined plane, and Ac is surface area (m^2)

Q_U, Q_L and Q_S respectively is useful energy, loss energy, accumulated energy in composite material, (W)

This work, useful heat gain is calculated as:

$$Q_u = A_C F_R\big((\alpha\tau)I_t - U_L(T_{ci} - T_a)\big) = mc_p(T_{co} - T_{ci}) \quad (2)$$

Where:

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m represents the air volume flow rate C_p represents the specific heat of air, F_R is heat remove factor, T_{co} and T_{ci} are the outlet temperature and inlet temperature of solar air collector. The thermal efficiency here is defined as:

$$\eta = \frac{Q_U}{A_C H R_b}$$

III. COLLECTOR CONSTRUCTION AND EXPERIMENT SETUP

A. Collector construction

The solar air collector, reported in this work, was designed, constructed and experimented under the meteorological condition of Ho Chi Minh city. The detailed configuration of the collectors under consideration is shown in Fig. 1. It consists of absorber plate, glass cover, fans and collector box with internal crimped baffles and the total collection surface area of collector is of 2 m^2. The collector is designed with internal crimped baffles that divide the collector into multiple channels. The cool air enters the bottom manifold and then move along the air channel, receives heat become hot air before leaving the collector. The heat absorption plate is coated with a heat-absorbing black paint with an absorption rate of up to 0.9 (± 0.02). The boundary and bottom layers of the collector using a 50 mm thickness of mineral wool (Rockwool). The schematic diagram of crimped baffle was shown as Fig.3

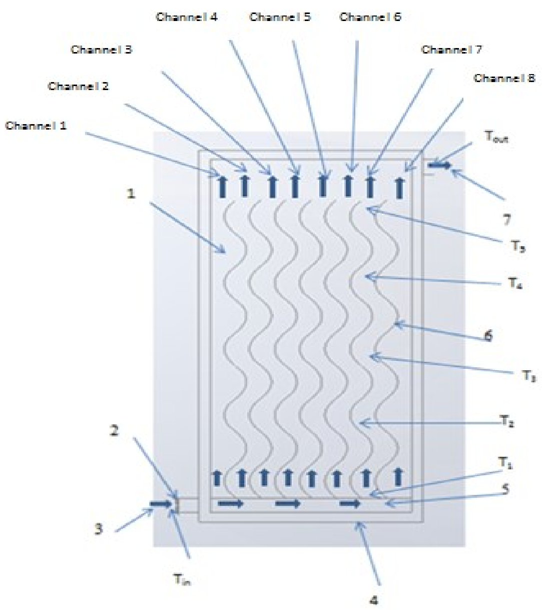

Fig. 1. Diagram of solar air collector with crimped baffles

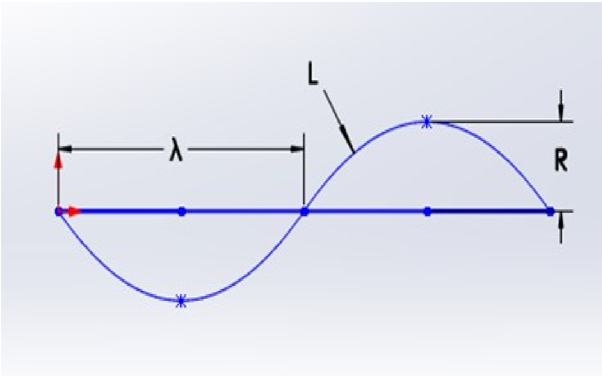

Fig. 2. Schematic diagram of crimped baffle: L-leght of crimped baffle; λ- arc leght; R- arc radius.

Fig. 3. Solar air collector with crimped baffles for experiment

B. Experimental setup

The experiments carried out at Dong Nai Province. The air flow inlet the collector is adjusted in the range from 0.01kg/s to 0.04kg/s based on the speed change of fan. In this work, the solar radiation was measured by pyranometer TM-750 (uncertainty is ±5%), the air flow was measured by the velocity meter HT-81 with an error of ±3%, while the ambient temperature and outlet temperature and absorption plate temperature were measured by K-type thermocouples (uncertainty is ±1%). Daylong experiments were carried out from 7:00 am to 5:00 pm, and values were recorded with the 5 minutes time interval and averaged over an hour and save in file excel for calculation.

IV. RESULTS AND DISCUSSION

In this study, a ansys program with the above mathematical model was developed to simulate the operation of solar air collector with with crimped baffles to evaluate the effects of

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the arc number, radius, lengh of crimped baffles and velocity to the air in channels of collector.

When the crimped baffles were installed in the solar air collector which will affect the moving of in the collector. When adjusting the arc number of crimped baffles with length L = 210.40mm, and radius R = 50mm, leads to that the movement of air in the collector relatively evenly distributed in the channels. The result is shown in Figure 4.

Fig. 5 shows the influence of the shape of arc radius R = 90mm, length of crimped baffle L = 264.77 mm to the temperature distribution of the air flow in the collector. When arc radius R = 50mm, length of crimped baffle L = 210.40mm were increased, the turbulent of the air flow in the channels of the collector is also increased.

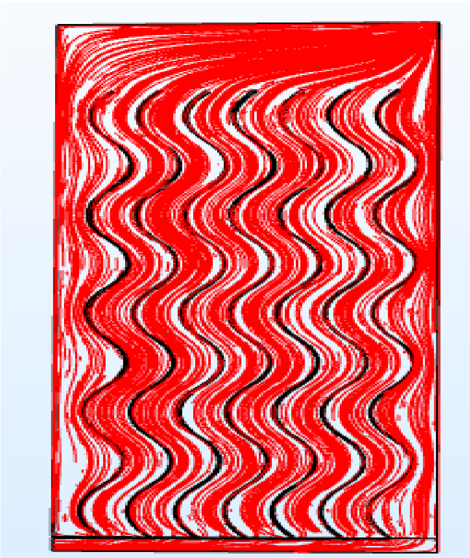

Fig. 4. Air flow shape of arc radius R = 50mm, length of crimped baffle L = 210.40mm

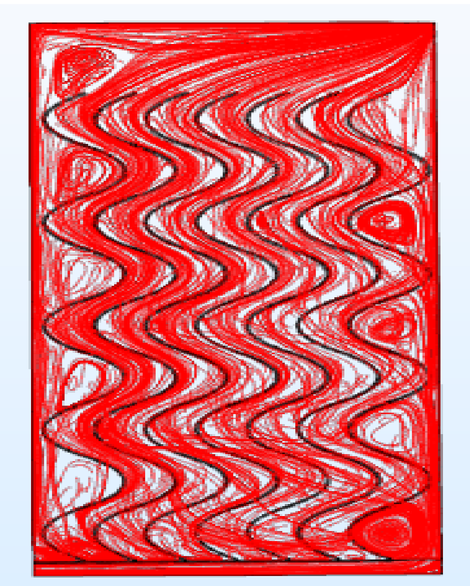

Fig. 5. Air flow shape of arc radius R = 90mm, length of crimped baffle L = 264.77 mm

Fig. 6 shows temperature distribution when air turbulent in the channels of crimped baffles. As seen in Fig. 6, the high temperature zone corresponds to the whirlpool region while the low temperature zone corresponds to the main flow zone. The reason is that the high temperature zone is caused by swirling air currents that keep the air in a local position and are constantly heated by an absorbing pad, which leads to higher vortex temperatures than non-existent areas. This is the cause of the large heat loss and reduces the heat recovery efficiency of the collector. Therefore, eliminating swirling regions in the air stream is an effective way to increase the heat collection efficiency of the collector.

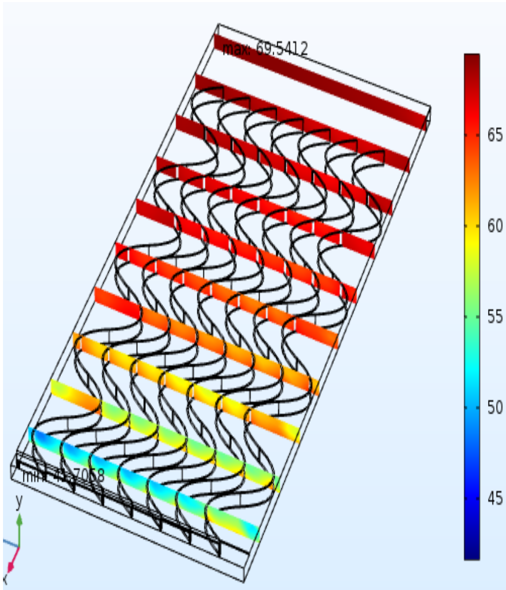

Fig. 6. Temperature distribution when air turbulent in the channels of crimped baffles

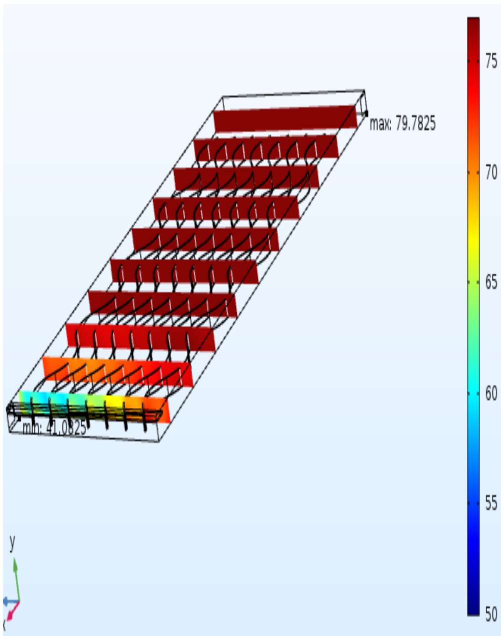

Fig. 7. Air temperature in the channels of solar air collector at t=11.6 AM

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Fig. 7 shows the air temperature in the channels of solar air collector at t=11.6 AM. As seen in Fig. 7, the inlet air temperature collector is equal the ambient temperature of 41 ºC and outltet air temperature of collector is 79.7 ºC at t=11.6 AM corresponding with the value of solar radiation is 920 W/m^2. The outlet air temperature is sutable the required temperature for drying applications.

Fig. 8 shows the temperature of absorber plate in the solar air collector at t=11.6 AM corresponding the solar radiation 625W/m^2. As seen in Fig. 8, the temperature of the absorber plate in ranges from 90 ºC to 120 ºC at 11.6 AM. This temperature is not constant, and fluctuation depends on the solar radiation and ambient temperature and velocity of air inlet collector.

Fig. 9 shows the effect of solar radiation on the outlet air temperature of collector during the day. The results of simulation and experiment of outlet air temperature of solar air collector indicated that the values of outlet air temperature of collector are strongy depended on the solar radiation. As seen in Fig. 9, when the values of solar radition ranges from 200 W/m^2 to 900 W/m^2, the values the outlet air temperature ranges from 36.3 ºC to 78.8 ºC, respectively. The error of simulation and experiment of outlet air temperature is 1.5%.

Fig. 10 shows the effect of solar radiation on the efficiency of collector during the intermittent cloud day. Fig. 9 indicated that the value of the efficiency of solar air collector in ranges from 66% to 68% in the intermittent cloud day, and this value is higher than in the clear day.

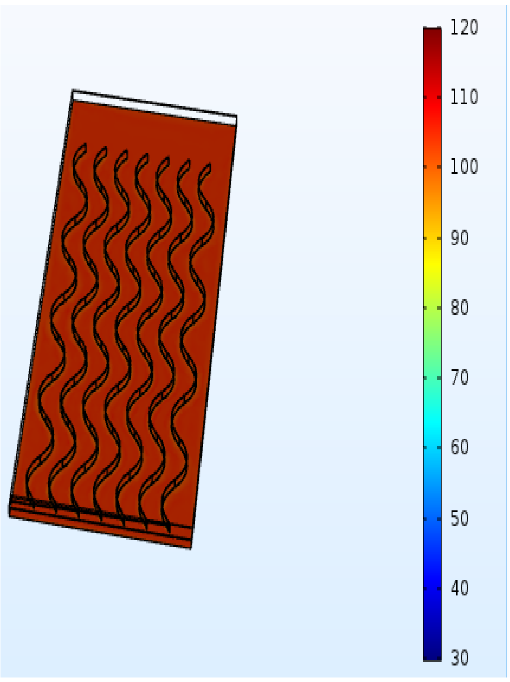

Fig. 8. Temperature of absorber plate in the solar air collector at t=11.6 AM

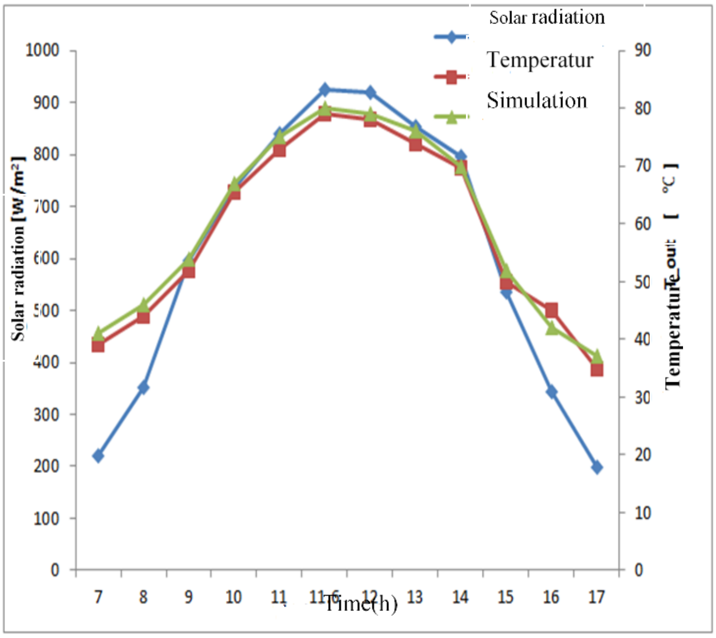

Fig. 9. The effect of solar radiation on the outlet air temperature of collector.

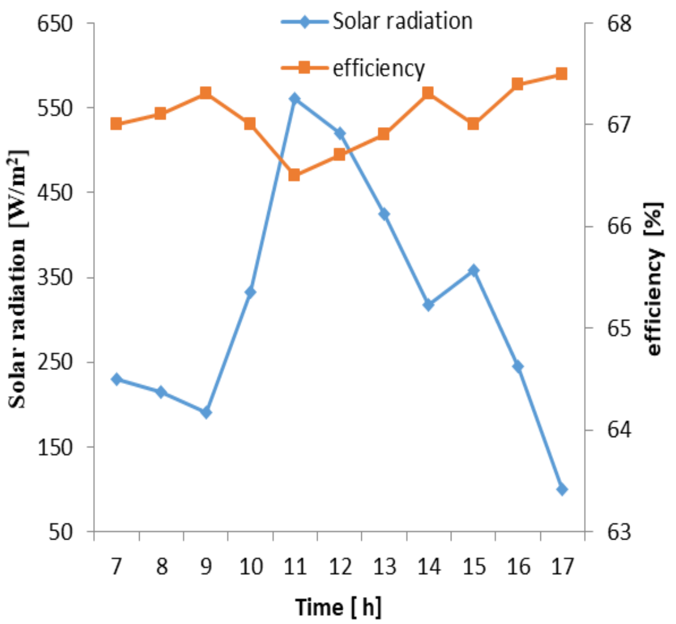

Fig. 10. The effect of solar radiation on the efficiency of the solar air collector in intermittent cloud day.

V. CONCLUSIONS

In this work, a solar air collector with crimped baffles has been developed. A detailed simulated and experimental study is conducted to evaluate the thermal performance and outlet air temperature of collector for drying application.

-The outlet air temperature of collector ranges from from 36.3 ºC to 78.8 ºC in case of the clear day.

-The thermal efficiency of solar air collector ranges 66% to 68% in the intermittent cloud day, and this value is higher than in the clear day. - The error of simulation and experiment of outlet air temperature is 1.5%.

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