Periodicals

Applied Mechanics and Materials

ISSN: 1662-7482

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ISSN print 1660-9336 ISSN cd 2297-8941 ISSN web 1662-7482

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Subscription

Irregular: approx. 20-30 volumes per year.

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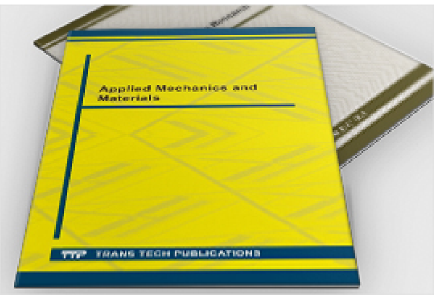

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ISSN	16609336
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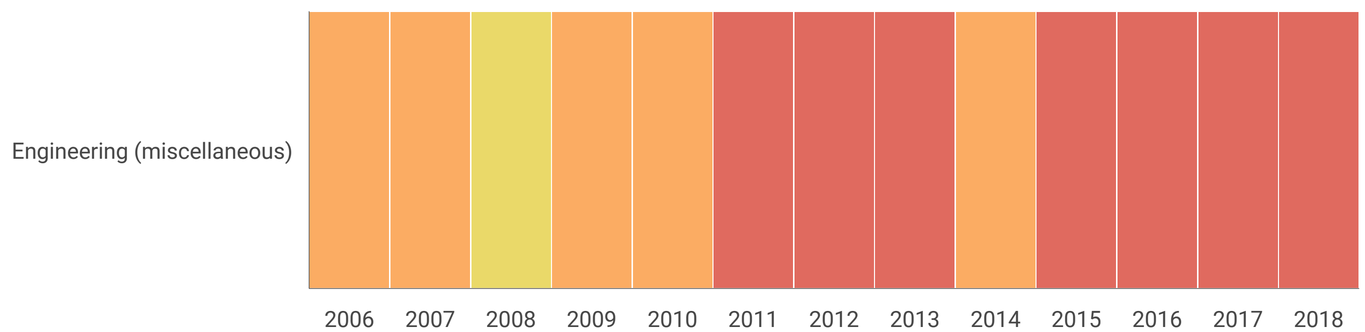

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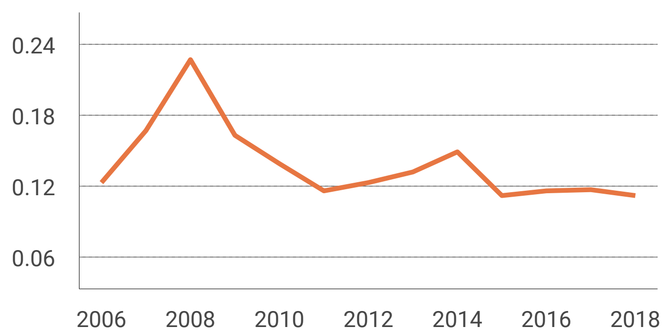

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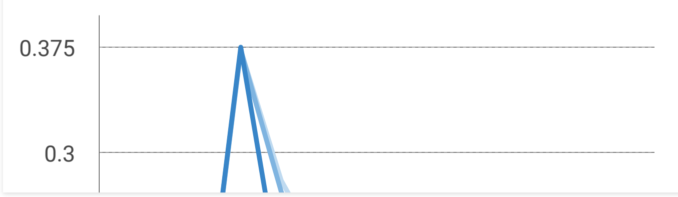

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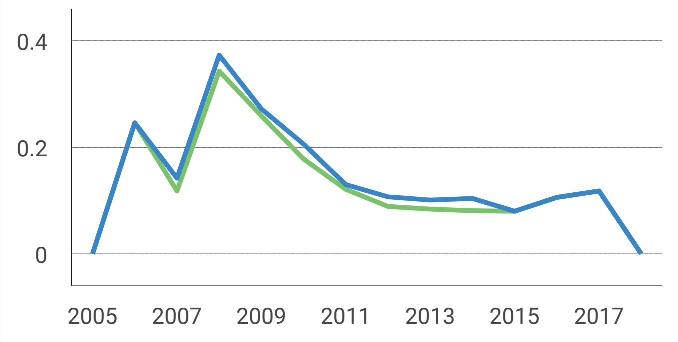

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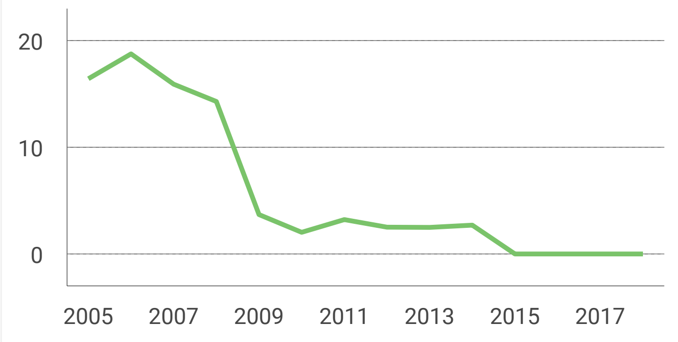

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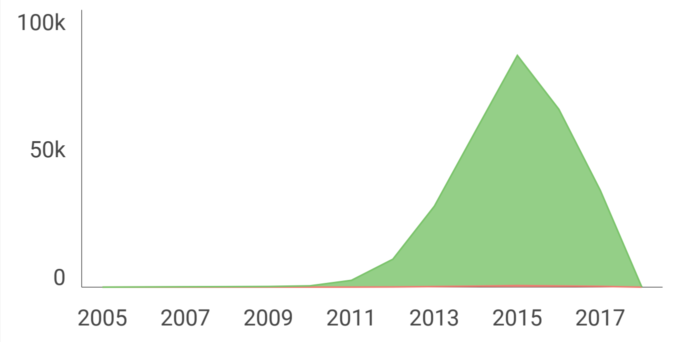

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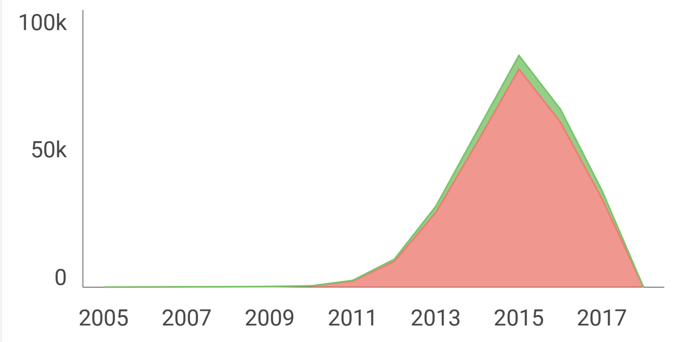

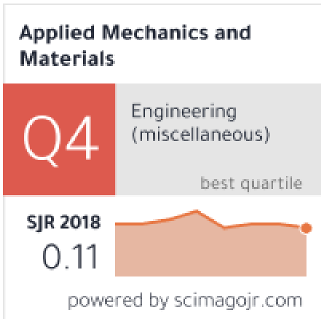

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Online available since 2014/Jan/08 at www.scientific.net

doi:10.4028/www.scientific.net/AMM.493.86

Experimental Studies on a Solar Air Heater Having V-Corrugated Absorber Plate with Obstacles Bent Vertically

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Keywords: solar air heater, obstacle, solar collector, v-corrugated absorber plate.

Abstract.

A solar air heater (SAH) is a simple heater using solar radiation that is useful for drying or space heating. Unfortunately, heat transfer from the absorber plate to the air inside the solar air heater is low. Some researchers reported that obstacles are able to improve the heat transfer in a flat plate solar air collector and others found that a v-corrugated absorber plate gives better heat transfer than a flat plate. Yet, no work of combining these two findings is found.

This paper describes the result of experimental study on a SAH with v-corrugated absorber plate and obstacles bent vertically started from 80^o to 0^o with interval 10^o on its bottom plate. Experiments were conducted indoor at five different Reynolds numbers ($1447 \le Re \le 7237$) and three different radiation intensities (430, 573, and 716 W/m^2).

It is found that the obstacles improve SAH performance. Both the air temperature rise and efficiency increase with inserting obstacles bent at any angle vertically. Unfortunately, the air pressure drop is increasing, too. Obstacles bent vertically at smaller angle (means more straight) give higher air temperature rise and efficiency. However, the optimum angle is found 30^o. The air temperature rise and efficiency will be 5.3% lower when the obstacles bent 30^o instead of 0^o, but the pressure drop will be 17.2% lower.

Introduction

As a country located in Equator, there is a lot of sunshine on surfaces in Indonesia. The sun's radiation energy can be converted into thermal energy by means of a solar collector. The sunlight transmitted by cover glass falls onto a plate which absorbs the heat. This absorber plate transfers the heat to the working fluid which is either water or air. Water has better thermal storage and higher convective heat transfer coefficient than air. Yet, air is much lighter and less corrosive than water. Furthermore, the heated air can directly be used for drying some farming product such as grain. Generally, the solar air heater is less efficient than the solar water heater, because air has less thermal capacity and less convection heat transfer coefficient. These encourage some research in solar air heater (SAH).

Most of SAH being investigated is flat plate type. It has a cover glass on the top, insulation on the sides and bottom to prevent heat transferred to the surrounding, a duct for the air flowing and an absorber flat plate. The air can flow over and/or under the absorber plate. To increase the convection heat transfer from the absorber plate to the air, a v-corrugated plate is used instead of a flat plate. SAH with a v-corrugated absorber plate can reach efficiency 18% higher than the flat plate under the same operation and condition [1]. A solar collector with a v-corrugated absorber is 10–15% and 5–11% more efficient in single pass and double pass modes, respectively, compared to the flat plate collectors [2]. For the same length of collector, mass flow rate, and air speed, it was found out that the corrugated and double cover glass collector gave the highest efficiency [3]. The results of mathematical simulation and experiment show that v-corrugated absorber was found to be more efficient than flat plate collector [4]. The corrugated surfaces give a significant effect on the enhancement of heat transfer and pressure drop. The Nusselt number of flow in a v-corrugated channel can increase to 3.2 – 5.0 times higher than in a plane surfaces while the pressure drop 1.96 times higher than on the corresonding plane surface [5]. The corrugated channel gave higher Nusselt number than the straight channel and a higher channel height gave higher Nusselt number for the flow with the same Reynolds number [6].

Besides increasing the heat transfer surface area, some also give effort to increase turbulence inside the channel with fins or obstacles. The result of experimental study done in turbulent flow regime (Reynolds number of 5000 to 25,000) showed that multiple 60° V-baffle turbulator fitted on a channel provides the drastic increase in Nusselt number, friction factor, and the thermal enhancement factor values over the smooth wall channel [7]. From the research of two kinds of rectangular fins which dimension are different but total area are the same, it was found that collector with fins type II, both free and fixed, was more effective than type I and flat-plate collector. The fixed fin collector was more effective than free fin collector [8]. The efficiency of collector and the air temperature was found increasing with the use of baffles. Baffles should be used to guide the flow toward the absorber plate [9]. The experiment and theoretical investigations gave result that heat transfer was improved by employing baffled double-pass with external recycling and fins attached over and under absorber plate [10]. The obstacles on the flat plate reduced the grape drying time, because they ensure a good air flow over the absorber plate, create the turbulence and reduce the dead zones in the collector [11]. From research on three-passages SAH with three different type obstacles placed on absorber plates, it was found that type III obstacles with flow in middle passage gave the highest efficiency and all collectors with obstacles gave higher efficiency than the flat plate [12]. The optimal value of efficiency was obtained for SAH with Type II obstacles on absorber plate in flow channel for all operating conditions and the collector with obstacles appears significantly better than that without obstacles [13]. The delta-shape obstacle mounted on the absorber surface enhances the heat transfer to the air and the heat transfer was higher if the obstacle was taller and its longitudinal pitch was smaller [14].

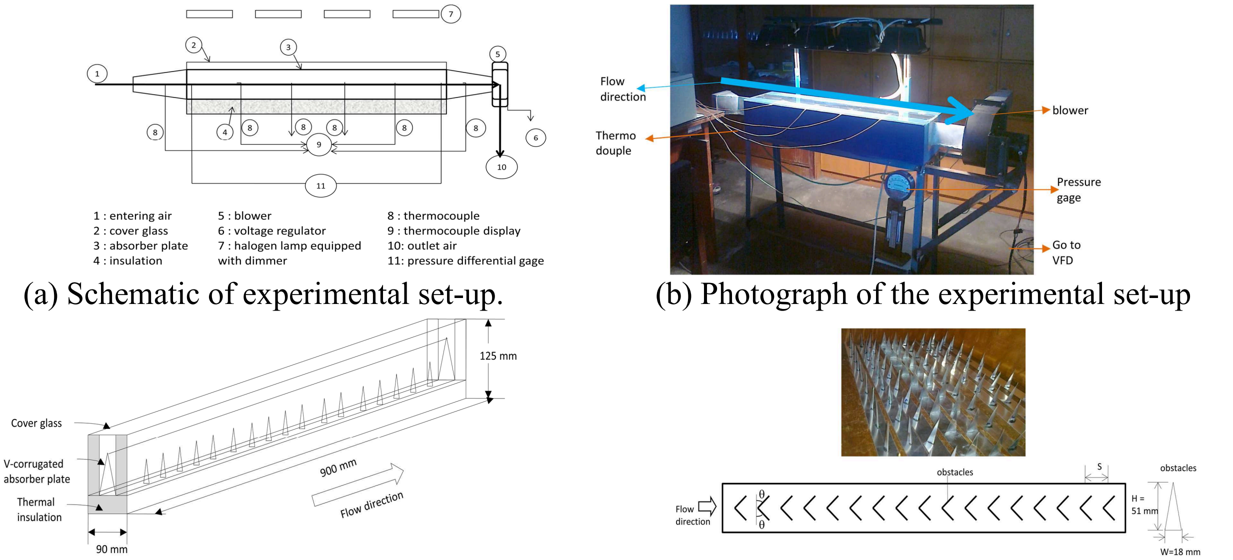
There are two findings that are important. First, the obstacles are able to enhance heat transfer in a flat plate collector and second, a v-corrugated plate gives better heat transfer than a plane duct. It is necessary to study the combination of these two findings. Since pressure drop is an important parameter in SAH, it is interesting to study the effect of bending the obstacles vertically, too. This paper describes the result of experimental study on a SAH with v-corrugated absorber plate and obstacles bent vertically on its bottom plate.

Experimental set-up

A small scale model of a SAH having v-corrugated absorber plate has been set up indoor. Its schematic view and photograph are shown in Fig. 1. The experiments were conducted in a laboratory of Mechanical Engineering Dept of Petra Christian University, Surabaya, Indonesia.

The solar collector's model was constructed with its bottom plate can be replaced with other plate having obstacles on it. The dimension of the model was 900 mm x 90 mm x 125 mm. The cover of the collector was made of a single 3-mm transparent-tempered glass. Black painted aluminum was used as the v-corrugated absorber plate. The apex angle of the v-corrugated plate was 20^o. The dimension of the absorber plate was 900 mm long, 87 mm hypotenuse, and 0.8 mm thick. The v-corrugated duct's cross section dimension was 30 mm width and 85 mm height. To prevent heat loss, the left and right walls of collector are insulated with a 25-mm Styrofoam each and a 35-mm Styrofoam for the bottom. The obstacles used were isosceles triangular plate with dimension are 18 mm wide and 51 mm height. The ratio of spacing to height of obstacles in sequence, S/H, equal to 1 or the percentage of air flow blockage in the channel was 36% when the obstacles are straight. Thus, there are 17 obstacles. In the experiment, the obstacles were bent vertically with angle started from 80^o to 0^o with interval 10^o. Obstacles with angle 0^o mean they are straight, not bent. Thus, there are nine set of obstacles inserted on the bottom plate as shown in Fig. 1 (d).

The experiments were set up indoor to ensure the same radiation intensity, wind's speed and ambient temperature. So, a bias result that effected by different outdoor condition can be avoided. The artificial sunlight was modeled by four 500-Watt halogen lamps. A pyranometer (Kipp & Zonen, type SP Lite2) placed on top of the cover glass was used to measure the radiation intensity received on the collector. To ensure the homogenous intensity and to generate some different intensity received on the collector, these lamps were equipped with adjustable turner individually. The experiments were conducted on three different radiation intensities, i.e. 430, 573, and 716 W/m^2.



(a) Schematic of experimental set-up. (b) Photograph of the experimental set-up

(c) Isometric view of duct (d) top view of duct and obstacles and photograph of obstacles

Fig. 1. Experimental set-up.

The temperature, humidity, and wind speed of air surrounding were well controlled. Some T–type thermocouple which accuracy are 0.1^{o}C are used to measure temperature of flowing air at inlet and outlet of the collector, temperature of the absorber plate (at four different locations). Each thermocouple has its own display. The pressure drop between inlet and outlet of the flowing air across the collector was also measured with a Magnehelic differential pressure gage which accuracy is 2 Pa and manometer using oil which accuracy is 1 mm. A centrifugal blower was used to induce the air flowing in the channel (1000 m^3/h, 580 Pa, 0.2 kW, 380 Volt input). The air flow speed was controlled by adjusting the motor's frequency using a variable-frequency drive (VFD). The experiments were performed at five different air inlet velocities, i.e. 1.0 m/s, 2.0 m/s, 3.0 m/s, 4.0 m/s, and 5.0 m/s or at Reynolds number of 1447, 2895, 4342, 5790, and 7237, respectively. The air speed was measured using digital anemometer which accuracy is 0.1 m/s.

The experiment was conducted on model without any obstacle and consecutively with obstacles bent with some angles. Thus, there are ten set experiments conducted for each air flow speed and radiation intensity. A VFD was used to adjust the frequency of the blower's motor to ensure a constant air flow speed during the experiment.

When the inlet and outlet temperature (T_i, T_o, respectively) and the mass flow rate of air ($\dot{m}_f$) are known from experiments and the value of air specific heat (c_p) is known, then the useful energy rate ($\dot{Q}_u$) can be calculated using Eq. (1).

$$\dot{Q}_u = \dot{m}_f c_p (T_o - T_i). \tag{1}$$

According to [15], this useful energy can be expressed in terms of energy absorbed by the plate from radiation received (I) and energy lost from the absorber, as given by Eq. (2).

$$\dot{Q}_u = F_R \tau\alpha A_C I - F_R U_L A_C (T_i - T_a). \tag{2}$$

The instantaneous efficiency of a collector relates the useful energy to the total radiation received on the collector surface as shown in Eqs. (3) and (4) [15].

$$\eta = \frac{\dot{Q}_u}{I\,A_c} = \frac{\dot{m}_f c_p (T_o - T_i)}{I\,A_c} \tag{3}$$

$$\eta = \frac{\dot{Q}_u}{I\,A_c} = F_R(\tau\alpha) - F_R U_L \frac{(T_i - T_a)}{I}. \tag{4}$$

In Eq. (4), the useful energy depends on parameters of construction material of the SAH and flow conditions, i.e. F_R, the collector heat removal factor, U_L, total heat loss coefficient, A_C, collector area, and ($\tau\alpha$), transmitivity of the glass cover times absorptivity of the absorber plate.

The inlet air temperature, T_i, usually equals to the ambient temperature, T_a, during experiments. Thus, Eq. (4) is modified to be Eq. (5) [15].

$$\eta = \frac{\dot{Q}_u}{I\,A_c} = F_o\tau\alpha - F_oU_L\frac{(T_o-T_a)}{I}. \quad (5)$$

Eq. (5) specifies that a plot of instantaneous efficiency as a function of $\frac{(T_o-T_a)}{I}$ will result a straight line which slope and intercept are F_oU_L, and $F_o\tau\alpha$. F_o is the collector heat gain factor. If the optical properties of the SAH, ($\tau\alpha$), are known, then F_o and U_L can be determined.

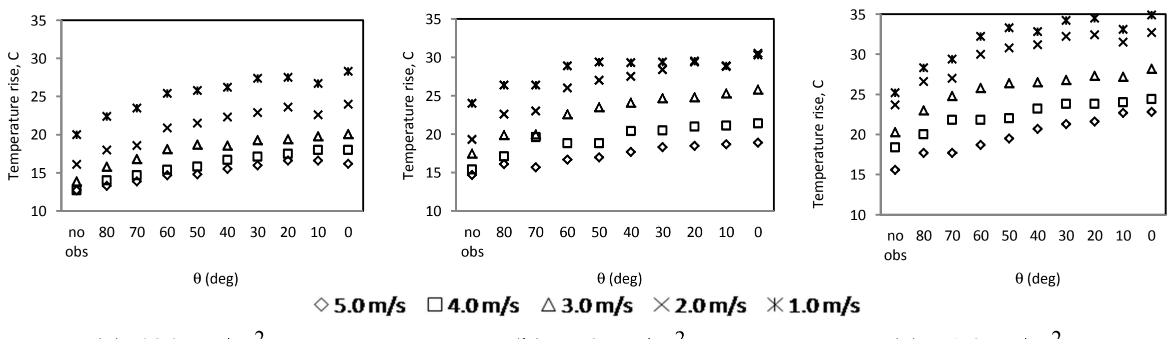
Results and discussion

The experiments were conducted on three different radiation intensities and five different air flow speed. The performance of SAH includes the air temperature rise, instantaneous efficiency, and air pressure drop. The air temperature rise is determined from ($T_o - T_i$) and the instantaneous efficiency is calculated using Eq. (5). The pressure drop is measured directly during experiments.

The radiation received on the absorber plate and the air flow rate crossing the SAH affect the rise of air temperature as shown in Fig. 2. It is higher when the air flow is lower at any radiation intensity and when the radiation intensity is larger at any air flow speed. Without any obstacle, SAH gave the lowest air temperature rise of 12.7°C and the highest of 25.2°C. The lowest air temperature rise is obtained at the lowest radiation intensity (430 W/m^2) and the largest air flow speed (5.0 m/s). The highest rise is acquired at the largest radiation intensity (716 W/m^2) and the smallest air flow speed (1.0 m/s). Obstacles increase the air temperature rise whether they are bent or straight. The straight (0° obstacles) increase the lowest air rise from 12.7°C to 16.2°C and the highest air rise from 25.2°C to 34.9°C.

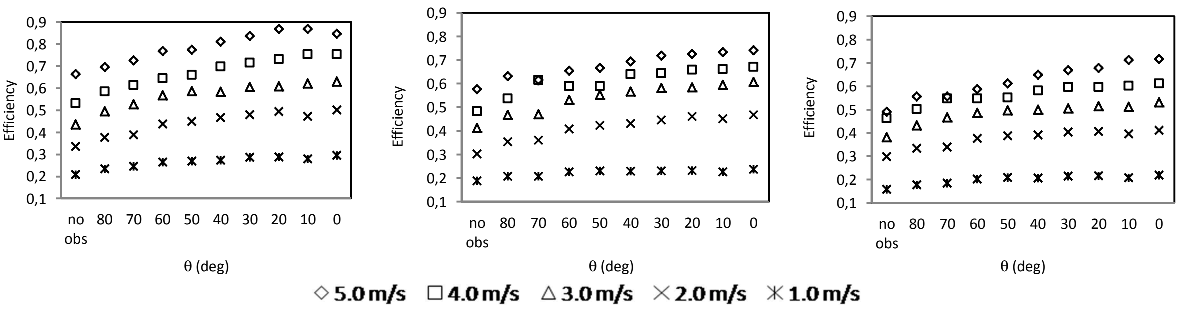
The air temperature rise in Fig. 2 and SAH's instantaneous efficiency in Fig. 3 decrease as the obstacles bent at larger angle. Fig. 2 show that the air temperature rise is almost the same when the obstacles bent at 30°, 20°, 10°, or 0° (straight) but the pressure drop is quite different as shown in Fig. 4. The air temperature rise and efficiency will be 5.3% lower when the obstacles bent 30° instead of 0°, but the pressure drop will be 17.2% lower.

Obstacles inserted in the flow generate turbulence and focus the air flow toward the absorber plate. When the obstacles slightly bent vertically, the air flow becomes obstructed. Some of the air will flow back causing the flow to recirculate and will reattach downstream before the next obstacles. This creates vortex near the obstacles and increase the turbulence in the air flow. Some of the air will flow in the small gap between the obstacles and absorber plate. This small gap forces the air to stay in contact with the absorber plate and to increase its velocity and turbulence. These make the heat transfer to the air flow and air pressure drop through collector increase when there are obstacles slightly bent vertically. There is something unpredictable happened, i.e. when the air flow is small (1.0 and 2.0 m/s), the temperature rise is very low as the obstacles bent at angle 10° at any radiation intensity. This phenomenon needs further research and numerical study or visualization to learn the flow around the 10° obstacles.



(a) 430 W/m^2 (b) 573 W/m^2 (c) 716 W/m^2

Fig. 2. The rise of air temperature at some air flow and radiation intensity for many configurations.

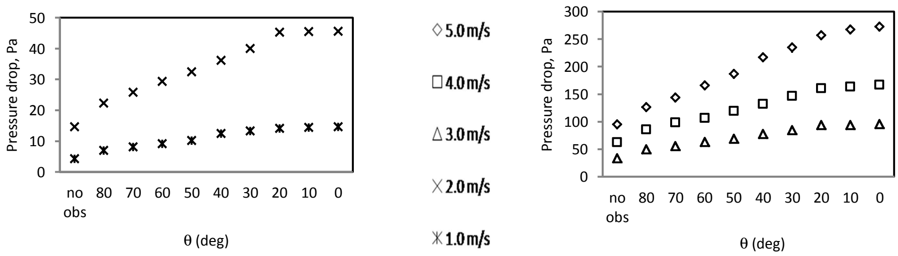


(a) 430 W/m^2 (b) 573 W/m^2 (c) 716 W/m^2

Fig. 3. Efficiency of SAH at some air flow and radiation intensity for many configurations.

The efficiency of the collector calculated using Eq. (3) shown in Fig. 3 give the consistent result with Fig. 2. As air temperature rise increased, the efficiency of the collector having obstacles also improved. For example, when inlet air speed is 5.0 m/s and radiation is 573 W/m^2, the efficiency of solar air heater with straight obstacles can reach 0.742 (74.2%) while it was only 00.577 (57.7%) when no obstacle used. The efficiency has the same trend with temperature rise, i.e. it is almost the same when the obstacles bent at 30^o, 20^o, 10^o, or 0^o (straight).

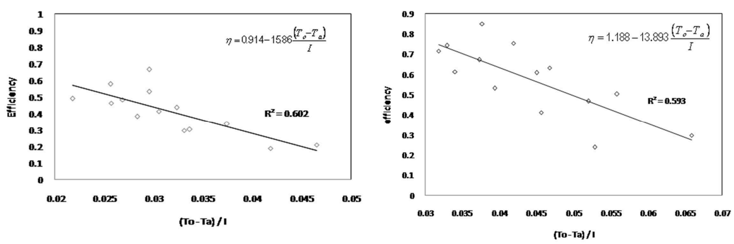
The static pressure of the air drops as it flows through the channel made by the v-corrugated absorber plate and the bottom plate. Fig. 4 shows the pressure drop for the ten SAH. To see the pressure drop more clearly, the graphs are separated, one for air flow speed of 1.0 and 2.0 m/s as in Fig. 4 (a), and one for air flow speed of 3.0 m/s, 4.0 m/s, and 5.0 m/s as in Fig. 4 (b). The pressure drop can decrease 17.2% when the obstacles bent at 30 degree instead of 0 degree when the air flow speed 5.0 m/s.



(a) Air flow speed of 1.0 and 2.0 m/s (b) Air flow speed of 3.0, 4.0, and 5.0 m/s

Fig. 4. Average pressure drop of air at different air flow speed and configuration.

The efficiency of SAH can be calculated using Eq. (5) as shown if Fig. 5. Due to space limitation, only two configurations of ten (no obstacle and 0^o obstacles) are shown. When some 0^o obstacles are inserted on the bottom plate, the efficiency is much higher than without obstacles. The slope of the linear regression is F_oU_L, and the intercept with vertical axis is $F_o\tau\alpha$.



(a) No obstacle (b) 0^o obstacles

Fig. 5. Efficiency of SAH with the temperature parameter $(T_o - T_a)/I$ at two configurations.

Using data that transmissivity (τ) of tempered glass is 0.87 and absorptivity (α) of aluminum plate is 0.92, then the collector heat gain factor (F_o) and the total heat loss coefficient (U_L) can be calculated as shown in Fig. 6. SAH without obstacle has the lowest F_o and the maximum U_L. The heat gain factor (F_o) increases and total heat loss coefficient (U_L) decreases as the obstacles bent at smaller angle. Yet, the value is not quite different when the angle is 30^o, 20^o, 10^o or 0^o. The F_o decreases as much as 4% and the U_L increases as much 3.5% when the obstacles bent at 30 degree instead of 0 degree.

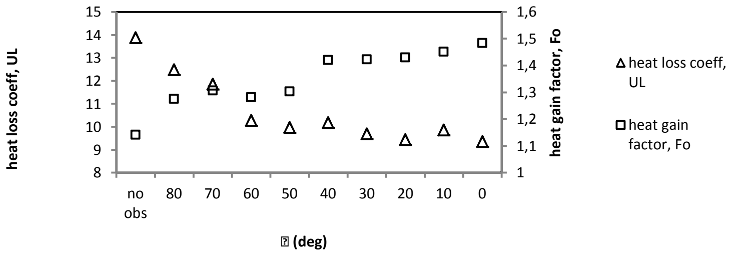


Fig. 6. The heat loss coefficient and heat gain factor of SAH with many configurations.

Conclusion

In the experimental study conducted, ten configuration of SAH were observed and compared. Following conclusions can be drawn:

- Obstacles placed on the bottom plate in a SAH with v-corrugated absorber plate improve the SAH performance. Both the air temperature rise and efficiency increase with inserting obstacles bent at any angle vertically. Unfortunately, the pressure drop is increasing, too.
- Obstacles bent vertically at smaller angles (means more straight) give higher air temperature rise and efficiency. However, the optimum angle is found 30^o. The air temperature rise and efficiency will be 5.3% lower when the obstacles bent 30^o instead of 0^o, but the pressure drop will be 17.2% lower.

Acknowledgement

Here, I am very grateful for the support from Kopertis Wilayah VII Jawa Timur, Kementerian Pendidikan dan Kebudayaan by providing Research Grant under contract no: 0004/SP2H/PP/K7/KL/II/2012.

References

[1] L. Tao, X. L. Wen, F. G. Wen and X. L. Chan, "A Parametric study on the termal performance of a solar air collector with a V-groove absorber," *Int. J. of Green Energy, 4,* p. 601–622, 2007.

[2] M. A. Karim and M. N. A. Hawlader, "Performance Investigation of Flat Plate, V-Corrugated and Finned Air Collector," *Energy 31,* pp. 452-470, 2006.

[3] C. Choudhury and H. P. Garg, "Design Analiysis of Corrugated and Flat Plate Solar Air Heaters.," *Renewable Energy Vol I, No. 5/6,* p. p. 595 – 607, 1991.

[4] A. A. Bashria, N. M. Adam, S. M. Sapuan and M. Daud, "Prediction Of The Thermal Performance Of Solar Air Heaters By Internet-Based Mathematical Simulation," *Proc. of the Institution of Mechanical Engineers,* p. 579 – 587, 2004.

[5] P. Naphon, "Heat transfer characteristics and pressure drop in channel with V corrugated upper and lower plates," *Energy conversion and management 48,* p. 1516 – 1524, 2007.

[6] Y. Islamoglu and C. Parmaksizoglu, "The effect of channel height on the enhanced heat transfer characteristics in a corrugated heat exchanger channel," *Applied Thermal Engineering 23,* p. 979–987, 2003.

[7] P. Promvonge, "Heat transfer and pressure drop in a channel with multiple 60° V-baffles," *Int. Com. in Heat and Mass Transfer,* vol. 37, p. 835–840, 2010.

[8] I. Kurtbas and E. Turgut, "Experimental Investigation of Solar Air Heater with Free and Fixed Fins: Efficiency and Exergy Loss," *Int. J. of Science & Technology,* vol. Volume 1, no. No 1, pp. 75-82., 2006.

[9] B. S. Romdhane, "The air solar collectors: Comparative study, introduction of baffles to favor the heat transfer," *Solar Energy,* vol. 81, p. 139 – 149, 2007.

[10] C.-D. Ho, H.-M. Yeh and T.-C. Chen, "Collector efficiency of upward-type double-pass solar air heaters with fins attached," *Int. Com. in Heat and Mass Transfer,* vol. 38, p. 49–56, 2011.

[11] A. Abene, V. Dubois, M. Le Ray and A. Oagued, "Study of a solar air flat plate collector: use of obstacle and application for the drying of grape," *J. of Food Engineering,* vol. 65, p. 15 – 22, 2004.

[12] H. Esen, "Experimental energy and exergy analysis of a double-flow solar air heater having different obstacles on absorber plates," *Building and Environment,* vol. 43, p. 1046–1054, 2008.

[13] E. K. Akpinar and F. Koçyiğit, "Experimental investigation of thermal performance of solar air heater having different obstacles on absorber plates," *Int. Com. in Heat and Mass Transfer,* vol. 37, p. 416–421, 2010.

[14] A. Bekele, M. Mishra and S. Dutta, "Effects of Delta-Shaped Obstacles on the Thermal Performance of Solar Air Heater," *Hindawi Publishing Corporation: Advances in Mechanical Engineering,* vol. 2011, p. 10 pages, 2011.

[15] J. A. Duffie and W. A. Beckman, Solar Engineering Of Thermal Processes, 2nd ed., John Wiley & Sons, Inc., 1991.

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