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Design of a Solar Tunnel Dryer Combined Heat with a Parabolic Trough for Paddy Drying

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Abstract. This paper presents the design, build and performance test of a solar tunnel dryer combined heat with a parabolic trough for paddy drying. A 2.27 m^2 parabolic trough stainless steel made with a single-axis solar tracking system produced hot water and delivered to the cross flow heat exchanger equipped with a solar tunnel dryer with the size of flat plate collector of 2.112 m^2. The system received solar radiation and reflected sunlight to the receiver at the focal point of a parabolic trough. At this point, a copper heat pipe with the inside diameter of 25.4 mm for water heating is placed. A parabolic trough is covered with plastic sheets for protecting the wind in order to prevent the heat loss by convection. The produced hot water is used to warm the air and is sent to the heat exchanger and the blower passes hot air through the drying chamber of solar tunnel to dry paddy. The average drying temperature was 57.73 °C. The paddy moisture content was assessed in a reduction from 49.96 to 15.61 MC (% d.b.) in 6 hours. The heated air was around 245.87 W, with the incoming heat in the solar tunnel dryer of 1271.84 W. The thermal efficiency of a solar tunnel dryer, a parabolic trough, and the overall efficiency were on the average of 28.31%, 8.73%, and 3.80%, respectively.

Introduction

Sun drying is the inexpensive method, but the quality of the dried produces is far underneath the international standards. Solar drying offers an occasion to yield quality dried products [1]. Drying is an energy intensive process. Higher prices and shortages of fossil fuels have increased the emphasis on using alternative renewable energy resources [2]. Drying of agricultural products using renewable energy such as solar energy is environmentally friendly and has less environmental influence. A parabolic trough is a kind of solar collector that is bent as a parabola in the other two, lined with a polished metal or mirror. The energy of sunlight, which comes in the mirror parallel to its plane of symmetry, is focused along the focal line. For sample, food may be located at the focal line of a trough, which causes the food to be heated. The mirror is oriented so that the sunlight which it reflects is focused on the tube, which contains a fluid, is heated to a high temperature by the energy of the radiation. The hot fluid can be used for many resolutions. Frequently, it is piped to a heat engine, which uses the heat energy to generate electricity. The trough is usually lined up on a north-south axis, and revolved to track the sun as it moves across the sky each day. Some research works of tunnel dryer were presented. Soponronnarit [3] and Soponronnarit et al. [4] established a combined paddy drying-storage hut that performed as a solar dryer and a storage unit. It was tested at a farmer's municipal in Thailand. The shelter can be used to store 10 tons of dry paddies. This dryer can decrease the moisture of paddy at the rate of 0.64% in one hour, and the return period is 2.3–14.8 years. Praditwong and Janjai [5] tested a drying cum storage system for paddy in 1988 and 1989. The results indicated that paddy could be dried from the moisture content of 27% (w.b.) to 15% (w.b.) in approximately 4–5 days through the dry season and 5–8 days for the period of the wet season. Ong and Than [6] informed an intermittent batch drying of paddy using indirect heating forced convection solar dryer in Malaysia. The trapezoidal-profile solar air heater was joined to the natural convection drying chamber. The latter was improved by using a centrifugal blower to permit hot air flow from the solar collector into the drying chamber. Johari and Jusoh [7] established a forced circulation batch dryer in Malaysia. Paddy in 138 kg was dried from a moisture content of 18% to 13% (wet basis) in 3 h. Ibrahim [8] also conducted a laboratory-size forced circulation solar batch dryer for paddy using a drying bin with a cross-section area of 0.6 m^2 coupled to a collector plate in the size of 0.84 m wide, 3.66 m long, and 0.27 m high. To dry a 100 mm deep bed of paddy from 20% to 13% moisture content in around 3 h. Tran et al. [9] investigated a continuous flow solar drying system using an electrically driven blower for air circulation in Malaysia. The solar air heater comprises of two flat-plate solar air heaters connected in series. Each one measured 2.44 m wide, 3.05 m long. Consequences showed that 150 kg of paddy could be dried from moisture contents of 20% to 13% (dry basis) in 4 hours. Thongprasert et al. [10] performed a forced convection solar dryer for drying paddy to overcome the limitations due to low buoyancy-induced air flow of natural convection solar dryers. The dryer consists of 3.74× 4.48 m^2 flat-plate solar collectors and a drying bin. Drying tests indicated that one ton of paddy could be dried from a moisture content of 17.21% to 14% (w.b.) in 1–4 days with the average energy consumption of the blower per drying a batch of about 7 kWh.

Material and Method

The Performance of a Combined Heat Solar Dryer. The performance of a solar tunnel dryer combined heat with a parabolic trough for paddy drying was evaluated by conducting paddy drying load test. A parabolic trough is aligned on a north-south axis, and rotated to track the sun as it moves across the sky each day in every 15 °/ hour with the assistance of sun tracking system. Water with the constant flow rate is used as a heat transfer fluid. Water is circulated within the heat exchanger connected to the drying chamber of the solar tunnel dryer. 68 kg of paddy was dried in 1 day (6 hours). Paddy was weighed before and after the drying in order to calculate the rate of evaporation of water from the paddy. The air temperature throughout the experiment, the temperature of the water in the pipe of the heat exchanger was measured and recorded. The air temperatures in the tunnel dryer, and in the drying chamber were measured as well. The K-type thermocouples are attached to the copper pipe on both the water inlet and outlet sides. An environmental temperature was kept by a data logger all six points; as shown in Fig. 1, which is recorded at the end of one day as well as the temperature of the outside air. To measure the radiation of the sun (I), a direct solar radiation in the units of W/m^2 was measured by a pyranometer and a shading rings in every 1 minute. Then plot the relationship between the temperatures of every tested point (temp-time of the day). The performance of a parabolic trough, the performance of the solar tunnel dryer, and the overall efficiency of the combined heat, solar dryer were calculated by the Eq. 1-3. The performance results of the system were compared between the solar tunnel dryer with and without a parabolic trough added.

The efficiency of the system can be calculated as follows;

$$\eta_{tunnel\ collector} = (m^{\circ}.Cp.\Delta T)/I_T\ A_{tunnel}\times 100. \quad (1)$$

$$\eta_{ptc} = Q_u/I_{bn}A_{ptc}. \quad (2)$$

$$\eta_o = \eta_{ptc} \times \eta_{\ tunnel\ collector}. \quad (3)$$

Experimental Setup

The experimental setup consists of a solar tunnel dryer combined heat with a parabolic trough for paddy drying, 5 points of K-type thermocouple, a pyranometer for direct solar radiation measurement, a 40 liter water tank, and a data logger for data recorded as shown in Fig. 1-2. Three selected clear sky days were considered for the test. The experiments conducted on May 29-30 and June 1, 2014 at Faculty of Industrial Technology Vallaya Alongkorn Rajabhat University Pathum Tani, Thailand.

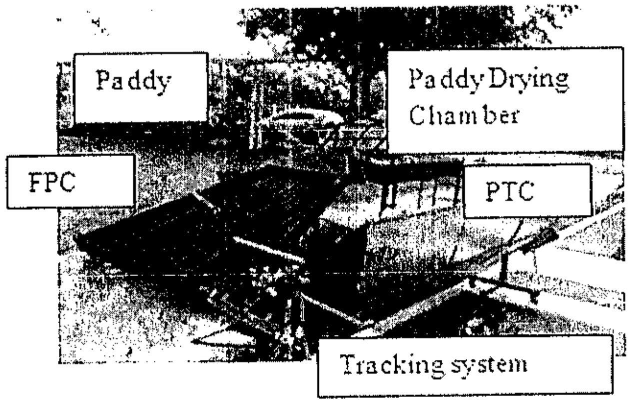

Fig. 1 Combined heat Paddy drying experimental test.

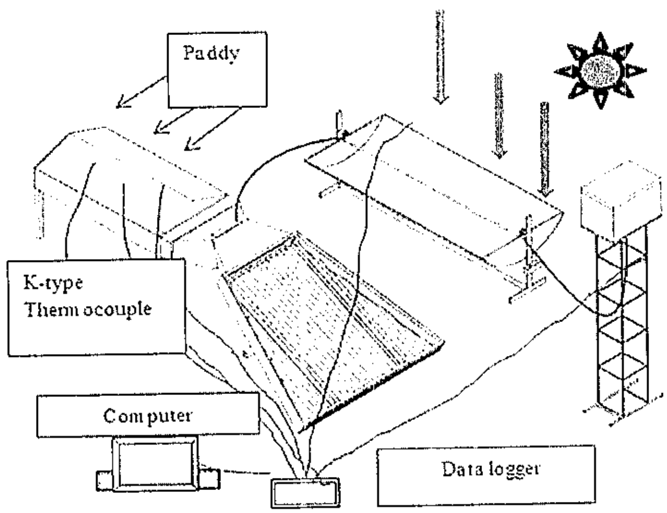

Fig. 2 Combined heat Paddy drying schematic diagram.

Experimental Results

3 selected sunny days of May 2014 were selected for solar tunnel dryer combined heat for paddy drying experiment test. The results show that the solar radiation was around 800 W/m^2, while a parabolic trough could absorb higher heat than a flat plate collector because parabolic trough absorbs direct solar radiation which gain more heat, that make the system derived more heat. The average parabolic trough efficiency is 8.73 %, with the average solar tunnel dryer efficiency of 28.31 %. The overall efficiency is 3.80 %. The relative of the incoming heat Q_{in}, the efficiency, and solar intensity versus time are shown graphically in Fig. 3.

Fig. 4 shows the ratio of moisture - drying time in a solar tunnel dryer combined heat with a parabolic trough for paddy drying. The rate of moisture content reducing was fast from hour 3 to 4 because the system received high solar radiation. Then became the constant value from hour 4 to 6. The dry basis of moisture content reduced to the required moisture at 15.61%.

The comparison of variation of moisture content of processed paddy in a solar tunnel dryer combined heat with a parabolic trough for paddy drying with conventional sun drying was conducted in a typical run on May 29-30 and June 1, 2014. Processed paddy was dried from a moisture content of 49.96% d.b. (time 3.5) to 15.61% d.b. (time 6.5) in 6 h as compared to 12 h of drying in open sun drying. The moisture content of the product was determined by oven drying method. After every 1 h, samples of the product were taken and weighed. Then they were placed in the moisture boxes that were placed in the oven at temperature of 105°C for 24 h.

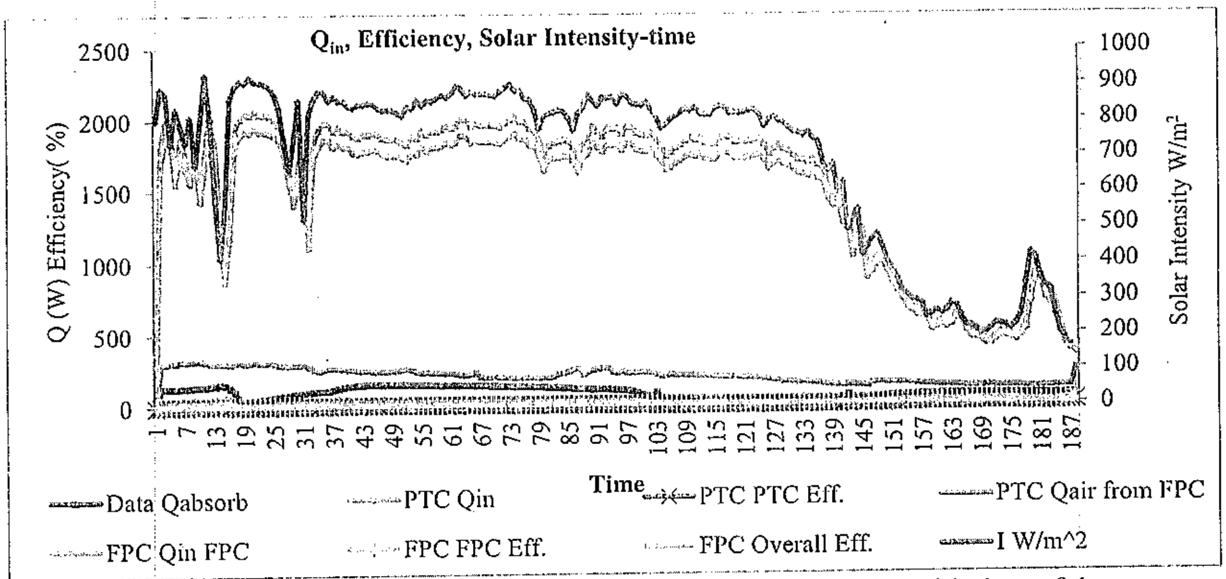

Fig. 3 Variations of the incoming heat, efficiency, solar intensity with time of day.

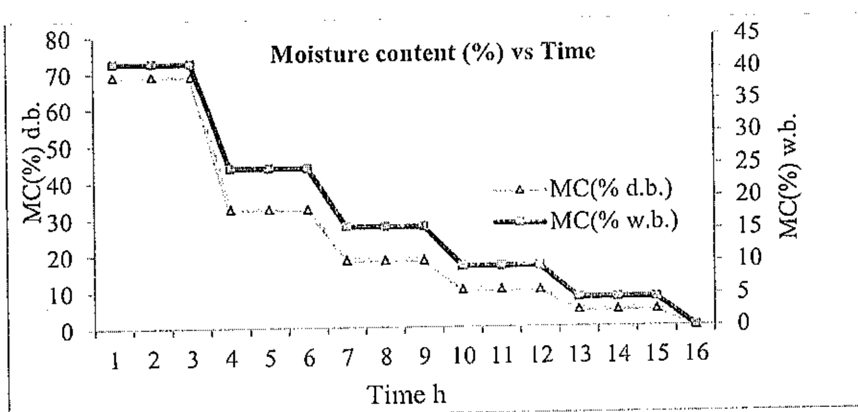

Fig. 4 Moisture content (%) and Time.

Summary and Conclusion

In this study, a solar tunnel dryer combined heat with a parabolic trough for paddy drying has been experimentally investigated, using a 2.25 m^2 parabolic trough as an assistance heater. The actual heat input to the system was measured at different temperatures. The thermal efficiency of the system depends on the solar radiation, absorbed heat capability of the receiver, and the aperture area of the collector. From the experiment we conclude:

1. The load tests by indicating that the average paddy drying temperature was 57.73 °C.
2. The paddy moisture content was assessed in a decrease from 49.96 to 15.61 MC (% d.b.) in 6 hours.
3. The heated air was around 245.87 W, with the incoming heat in the solar tunnel dryer of 1271.84 W.
4. The thermal efficiency of a solar tunnel dryer, a parabolic trough, and the overall efficiency were on the average of 28.31%, 8.73%, and 3.80%, respectively.
5. The drying time could be reduced by one second for paddy for the same level of final moisture content, and without causing any considerable change in the quality of the dehydrated product.

The constructed solar tunnel dryer combined heat with a parabolic trough for paddy was found to be the best among the natural convection solar dryers for drying paddy. A parabolic trough could produce heat energy supply to a solar tunnel dryer and boost the rate of paddy drying, but its disadvantage is the low capacity rate of drying and require more operating and maintenance cost.

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