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PARA-RUBBER SHEET DRYING WITH THE COMBINED SOURCES OF SOLAR ENERGY AND SOLAR POND

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Abstract

The objectives of this research was to study the efficiency of two para - rubber sheet drying methods; solar drying and solar drying combine solar pond. The solar energy house of 1.8 x 2 x 3 m^3 with the capacity of 100 sheets was constructed in Amphoe Mueang Khon Kaen district,Khon Kaen province Thailand, in conjunction with the solar pond which was 8 meters in diameter and 2.5 meters in depth. In order to evaluate energy using aspect, the energy using studies were divided to 2 systems. System I was only solar drying. System II was using solar drying at day time and solar pond at night time. The initial humidity of para-rubber sheet was about 29 - 33% respectively. The experimental results showed that the temperature distribution in the solar energy house was uniform. The night time average inside temperature solar energy house was higher than that outside 3°C, 10°C for system I, II respectively. The solar energy house was that system I required the longest time 120 hours while system II required the shortest time 84 hours. Moreover, it was found that, the humidity of para-rubber sheet range was about 0.5 – 1.25% after drying.

Keywords:*solar energy; parabolic dish; Thermoelectric,*

1. Introduction

Thailand is currently the largest natural rubber (NR) producing and exporting country in the world. Natural rubber is commercially produced in four forms: ribbed smoked sheet (RSS), block rubber, rubber concentrated latex, and miscellaneous other forms. The factors affecting the drying of rubber sheets are temperature, velocity and humidity of the drying air. The drying time can be reduced and the quality of the rubber sheets can be improved. (Prasertsan et al., 1991;Wattana et al., 2005)

Rubber sheet drying, which is one of the most important parts of the natural rubber industry, can be divided into two types according to the processes of drying (Office of Industrial Economics ., 2013) According to the survey of rubber sheet smoking factories, (Prasertsan et al., 1991;Wattana et al., 2005) in the southern part of Thailand, the quantity of rubber tree fire-wood used to smoke rubber sheets each year is approximately 229,994 m^3 (1 m^3 of firewood = 600 kg). In other words, such vast amount of firewood can generate heat to dry rubber sheets at 226.8 GJ. Therefore, it follows that costs associated with drying can be saved if energy consumption can be reduced. (Beymayer et al., 1993) introduced the solar air heater to the rubber sheet smoking system. It was found that the drying rate was faster; the normal smoking took process took 12 days, but only 5-6 days with the solar air heater. (Nilchuewong et al., 2012) studied rubber sheet drying with hot air and a conservatory. Their results showed that the drying rate of the hot air drying was better. However, the

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energy consumption of the hot air drying ranged from 8–20 MJ/kg of water evaporated. The quality of the rubber sheets from both experiment conditions passed the local market criteria (Grade 1–3) and the yellowness of dried rubber sheets proportionally varied with drying temperatures.

Many previous studies have used solar energy to dry raw rubber sheets during daytime but there has been no reports of harnessing solar energy for night time drying. This research has investigated a novel method of using solar energy to dry rubber sheets both day and night. The rubber drying plant is designed to combine heat from solar energy and a solar pond in order to reduce the amount of time required in the production process for rubber sheet drying. The drying plant has additionally provided good quality rubber sheets with low moisture contents and desirable appearance. The current paper presents the design and testing of the new system. Results are then discussed and interesting conclusions are made.

1.1 Solar pond

A solar pond is a device that collects and stores solar energy. It can operate continuously throughout the year. Solar ponds collect energy from solar radiation. The radiant heat is collected at the bottom part of the pond and this amount of heat can be used later. The temperature difference between the top and the bottom of the solar ponds can be as high as 50–60 °C. Thermal energy stored in the solar pond can be utilized for heating of buildings (hydrophonic), power production and desalination purposes (Akbarzadeh et al., 2005).

The structure of a solar pond is shown in Fig. 1**.** It is noted that the size of the pond depends on the aim of energy use such as water heating, crop drying, desalination and electrical power generation. There is an amount of saline inside the pond. Generally, the saline solution is sodium chloride or magnesium chloride solution. The pond can be divided into three regions namely the upper convective zone (UCZ),the middle non-convective zone (NCZ) and the lower convective (LCZ).

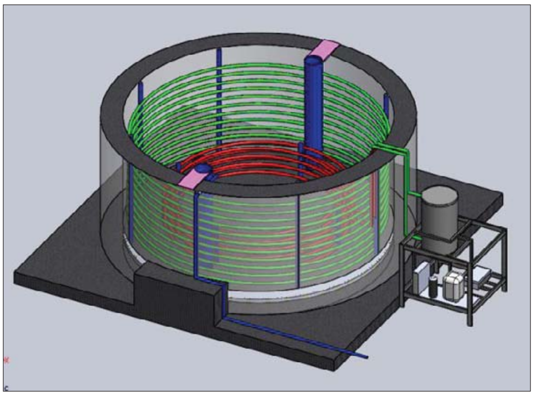

Fig. 1: Schematic of the solar pond

The upper convective zone is located at the top of the pond. The temperature of this zone is close to ambient temperature. The salt concentration is also near that of clean water. Due to the contact between the top layer of the UCZ and the ambient air, there is inevitable energy loss from convection and evaporation.

The middle zone, the NCZ, is sandwiched by the UCZ and the LCZ. In this zone, the salt concentration changes with depth measured from the interface of the upper convective zone and non-convection zone. An increase of depth from this interface results in an increase in salt concentration. The function of this zone is to inhibit heat convection away from the LCZ. However, there is an optimal thickness such that heat can be transferred from the UCZ downwards without significant heat loss, yielding the high efficiency of energy storage inside the pond (Andrew et al., 2005).

The bottom zone, the LCZ, has the highest salt concentration which is also uniform. When the pond receives heat from solar radiation, the heat penetrates through the upper and non-convection zones to be stored at the LCZ. Thus, it is clear that heat energy is extracted from this zone for useful applications.. Two methods have been used to extract energy from solar ponds. Firstly, fresh water or glycol is circulated through a submerged heat exchanger in the pond. This method is limited by heat transfer by natural convection within the lower convective zone, and the surface area of the submerged heat exchanger can be determined accordingly. Secondly, brine from the lower convective zone is circulated through an external heat exchanger installed outside the pond. This brine-withdrawal method requires less heat exchanging surface, but the flow-distribution system must be carefully designed to avoid erosion of the non convective zone. In the present research it is shown that by combining thermosyphons and thermoelectric cells, it would be possible to utilize the temperature difference existing between the top and the bottom of a solar pond and produce electric power in a fully passive way, i.e. no moving parts. In such a scheme, the heat is transferred by the thermosyphon from the lower region of the pond to the 'hot' side of thermoelectric cells which maintains a good thermal contact with the top of the thermosyphon tube. The 'cold' sides of the cells are in contact with the cold environment of the top layer of the solar pond (Tundee et al., 2010; Randeep et al., 2011).

2. Experimental setup

The experimental setup was composed of a solar pond and a rubber drying plant as schematically illustrated in Fig.2. The solar pond, made of concrete, was a cylinder with a diameter of 800 cm, height of 250 cm and the pond's wall's thickness of 25 cm. Within the solar pond, two sets of heat exchangers (dubbed Set 1 and Set 2) were installed. Set 1was installed within the lower convective zone and Set 2 was installed at the inner wall of the solar pond 50 mm away from the wall. the temperature output had reached a steady state, K-type thermocouples ($\pm$0.5 °C accuracy) were also installed in the solar pond at an interval of 0.1 m from the bottom floor to the upper convection layer in order to measure the heat accumulated within the solar pond. Data is collected every 1 minute using a temperature recorder Yokogawa, DA100$\pm$0.1°C with 24 channels and subsequently stored in a data acquisition device for further analysis. 100 sheets of rubber were stored in the rubber drying plant which was 1.8 × 2 × 3 m in size. The tests were carried out three times by using three flow rates of water from the solar pond to the heat exchanger, which were 3, 2.5 and 2 litters per minute respectively.

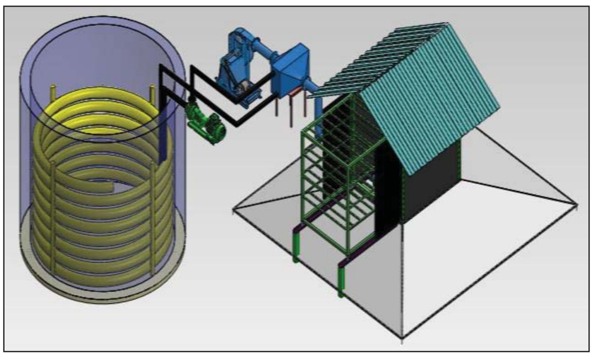

Fig. 2 : Schematic view of the solar pond and the heat extraction system.

3. Results and discussions

3.1 The effect of solar radiation

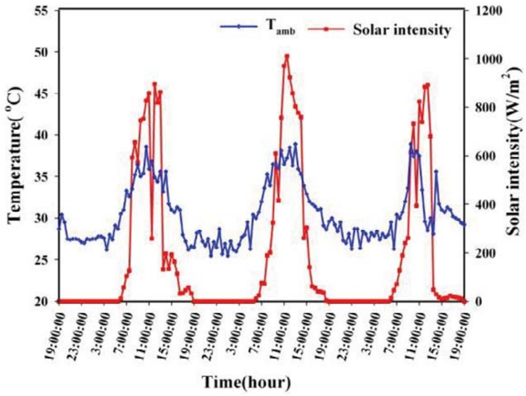

Fig. 3: Time variation of solar radiation on the test site over the three days of test duration.

Fig. 3 shows the time-varied solar radiation during the experiment using a pyranometer measuring the solar radiation in experiment area. The data logger was used to record radiation values every two minutes and average values were calculated every 30 minutes, as shown in Fig. 3 by collecting data over three days during the drying period . It can be seen that the thermal radiation values changed due to changeable day-to-day weather factors including cloudiness, sunlight or rain. Having many clouds in the sky on the third day of the experiment, the radiation value was noticeably reduced.

3.2 The density of solution in the solar pond

Fig. 4 shows the density of the solution in the solar pond, after salt had been added for 2, 30 and 60 days. The density value of the solution remained constant throughout the two-month period. The density profile shows is divided into three layers. The top layer, the UCZ has a thickness of 20 cm and the density of the solution is similar to water. It is followed by the NCZ. The density value of the solution increases steadily downwards and becomes constant at the onset of the LCZ. The thickness of the NCZ was 150 cm. The final layer, the LCZ, has a thickness of 80 cm. Its density is constant throughout the layer, similar to the saturation value of saline solution.

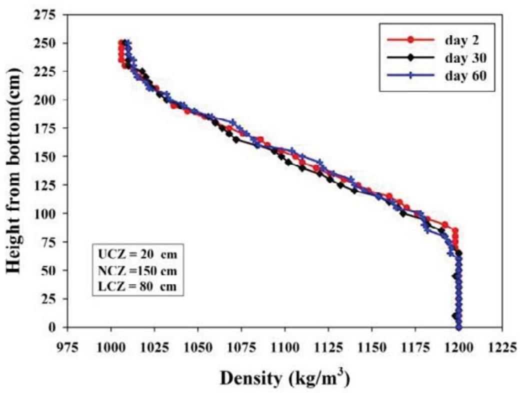

Fig. 4 : Density profile of the salinity gradient solar pond located at RMUTI Isan in Summer.

3.3 Internal temperature in the solar pond

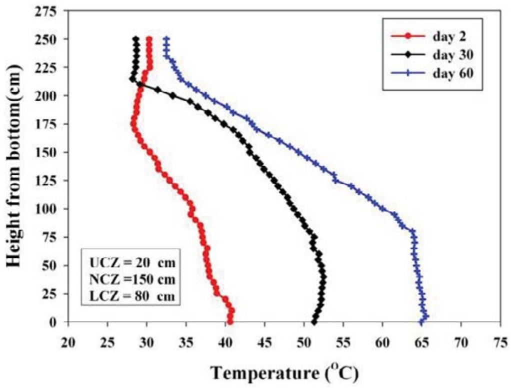

Fig. 5: Temperature profile of the salinity gradient solar pond located at RMUTI Isan in summer.

Fig. 5 shows the internal temperature of the solar pond, measured on the same day as the density profile in Fig.4. The temperature of the solar pond was measured at every 5 cm from the LCZ at the bottom of the solar pond to the NCZ and the UPZ. The figure shows that when the solution had been added to the pond for two days, the internal temperature of the solar pond in the layer of LCZ was approximately 41 °C, and the value decreases with the height from the solar pond's floor. The temperature in the UPZ was approximately 29 °C, close to ambient temperature and uniform through the entire layer. When the test duration of 2 months days had elapsed, the temperature in the layer of LCZ reached approximately 65 °C, which gradually reduced with height above 80 cm from the floor to the bottom boundary of the UPZ.

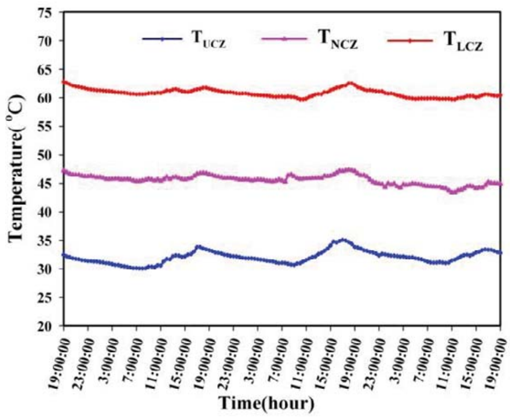

Fig. 6: Average temperature in the solar pond at the UCZ, NCZ and LCZ.

Fig. 6 shows average temperature in the solar pond at the UCZ, NCZ and LCZ. Thermocouples were installed in the solar pond with a distance of 5 cm from the bottom of the solar pond up to the upper layer. The average values were calculated from five measure points in the 20-cm-thick UCZ. . The temperature in the UCZ was similar to the ambient value. It can be seen that during daytime, when the temperature of the atmosphere was high, the three average temperatures increased accordingly. At night, when the atmospheric temperature dropped, the temperature in the UCZ dropped as a result. By contrast, the average temperature of the NCZ exhibited small reduction or increase during the night and daytime respectively. In the rubber drying experiments, during the period from 6:00 AM to 18:00 PM, thermal energy came from the sun directly. From 18:00 PM to 6:00 PM, stored energy in the solar pond is extracted for drying, hence a steady night time temperature drop of the solar pond in Fig. 6. The temperature in the solar pond increased again upon receiving daytime solar energy.

3.4 The features of rubber sheet in the rubber drying plant

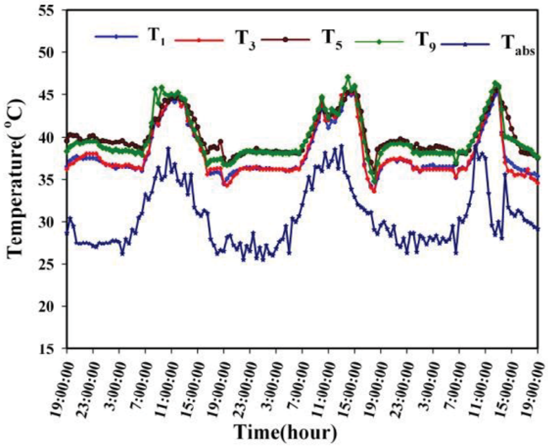

Fig. 7: Time-varied ambient temperature and temperature in the rubber drying plant measured at 4 locations T1, T3, T5 and T9.

Fig. 7 shows the temperature in the rubber drying plant at four points in the rubber drying plant. There were four measurement locations in the drying plant: T1 and T3 were installed at the top of the plant whereas T5 and T9 at the bottom. Ambient temperature was also recorded. The figure shows similar values amongst all the four locations, which changed in accordance with ambient temperature. Under sunlight, the temperature rise in the rubber drying plant above the atmosphere varied around 15-20 °C during the day, and around 10 °C during the night when the rubber drying plant was heated by the solar pond.

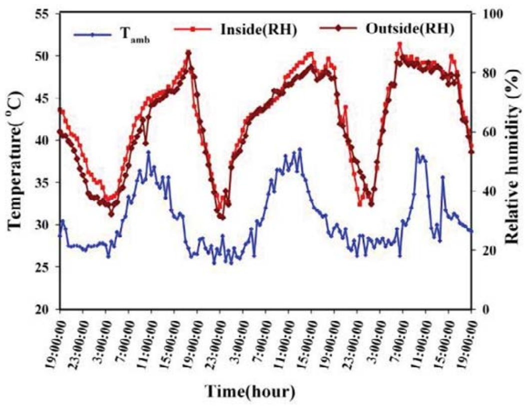

Fig. 8: The humidity values in the rubber drying plant.

Figure 8 shows humidity values in the rubber drying plant, It can be seen that humidity in the rubber drying plant follows the temperature outside. When the outdoor temperature increased, the indoor humidity increased. It can be observed from 15.30 PM, the humidity in the rubber drying plant was about 25-38 percent. During the day, the humidity outside the plant was about 23-35 percent. During the night, the humidity in the rubber drying plant increased because the temperature outside the plant decreased, thereby lowering the saturation level and consequently increasing relative humidity. Humidity in the drying plant at 04:30 AM was about 87-82 percent, but 80-84 percent outside.

Fig. 9: Features of the rubber sheets (a) before and (b) after 2 days of drying.

Fig. 9 shows the features of the rubber sheets before drying and after drying for 2 days. The rubber sheets were installed on the racks in the drying plant. The rubber sheets before drying were raw rubber sheets. They were pre-dried in the air to drain before loading into the drying plant. 100 rubber sheets (maximum capacity of the plant) were loaded in the experiment where they were placed on nine panels. Eight panel had 12 rubber sheets, but the ninth panel had four. The weight of a rubber sheet before drying was about 1 kg.

After drying for two days, the rubber sheets appear pale yellow, clear but with some white partially-wet patches.

Fig. 10: The features of rubber after drying for three days in solar drying chamber

Fig. 10 shows the features of rubber sheets after drying for three days in the drying chamber, the rubber sheets appeared clear, pale yellow and evenly-coloured which would have been difficult to achieve by smoking method. When subjected to further drying, the moisture contents of the rubber sheets were unchanged, rendering them suitable for discharge after only 3 days of drying.

4. Conclusions

The solar drying chamber for para rubber sheets that works in conjunction with the solar pond was investigated. During daytime, the drying plant uses solar energy for drying and then thermal energy extracted from the solar pond at night. The system has been shown to elevate the temperature of the rubber drying plant from ambient by 10 °C at night, and shorten the length of drying time by two days compared with drying without a solar pond, and faster by up to 6 days compared with typical sun drying in the open air. The rubber sheets that passed through the current drying process appeared light yellow, evenly-coloured and without any black dots or air bubbles which are desirable characteristics of high-grade rubber sheets.

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