Performance evaluation of hot liquid transmitting system in a solar dryer

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ABSTRACT: The aim of this study is to evaluate the Operation of System of hot liquid transmission in an automatic solar dryer. In this research the automatic solar dryer in order to use solar energy for drying agricultural crops, was designed and constructed. we evaluated the influence of time setting of pump timer in 3 levels (5, 10 and 15 Minutes) and the environment temperature in four levels of (24, 28, 32 and 36 Degree Celsius) on the function of the solar collector and the dryer chamber. The measured parameters included the temperature of the solar collector, the maximum and the minimum temperature of the drying chamber. From variance analysis of data showed that Influence of environment temperature was significant in 1% on temperature of the solar collector, maximum and the minimum temperature of the dryer chamber. Also it showed that Influence of setting of the pump timer was significant in 1% on maximum and the minimum temperature of the dryer chamber. But it was insignificant on the temperature of collector. The results of this study showed that by increasing the environmental temperature, rises temperature of collector and dryer chamber was obtained, also in order to make a moderate and uniform temperature, 10 minutes were calculated for the time setting of the pump’s ideal level.

Keywords: agricultural, automatic, Designing, hydraulic pump, Solar collector, Solar Energy

INTRODUCTION

Solar energy is a big potential for using at low temperature ranges and it is an ideal choice due to the lack of environmental pollution, ease of use and reduction of manufacturing costs for dryers and heating systems. The main part of solar heating systems is the solar collector; so efficient and suitable designing of the collector is one the most important factors for economic feasibility of these systems. Solar collector is a kind of heat convertor which converts the solar energy into the thermal energy. Flat plate collectors, are the most common and simplest equipment to convert the solar radiations into useful energy. These kinds of collectors are used for low to moderate temperature production, maximally 100°C above the ambient temperature (Duffie and Beckman, 2001). The most common usage of flat plate collectors are supply of warm water and heating at homes, greenhouses and industrial processes, air conditioning and finally drying of agricultural crops. During the research program conducted on rise and fall of temperature inside the dryer chamber, at one University, solar dryer shows 29.5°C increase at dryer chamber based on 18°C maximum environmental temperature and 6°C increase based on 7°C minimum environmental temperature, as a result, this temperature difference causes a convection in a dryer chamber and consequently causes agricultural crops drying with solar energy (Sharma et al, 2004). A portable multi-shelf solar
dryer was designed for use in rural areas and farms. High capacity, utilizing the solar energy directly and indirectly and usable at different seasons are the features of these kind of dryers (Singh S and Singh P, 2004). The performance of a dryer with sun traceability was evaluated. Dryer was made of absorber steel and the collector was made of transparent polyvinyl chloride (PVC) and its collector had to be manually adjustable of 30 degree in order to track the sun. The results of this study indicated that Reached temperature at dryer increases around 10°C and the drying time is reduced significantly (Ammari and nammir, 2003). Flat plate collectors, based on their heat transfer fluid are divided into two subgroups, air and water collectors (Dewinter, 2000). Performance of a solar dryer equipped with hot water tubes was examined, the collector of this dryer is connected to a hot water tank, the water heated by solar radiation and transferred into the dryer chamber by tubes. Results indicated, hot water using at agricultural crops solar dryer increases thermal efficiency of the dryer up to 30% and the quality of the dried products, significantly improves (Lamnatou et al, 2012). Poor insulation of air-heat collectors due to the open valve at the input channel, low volumetric heat capacity of air and low capacity of the heat transfer between the absorber and the air are the restrictions of using air as a heat transfer fluid at air collectors (Grupp et al, 2002); while high volumetric heat capacity and High thermal conductivity of water are the advantages of using water as heat transfer fluid. Hence, the present research is intended to use water as a heat transfer fluid instead of hot-air.

MATERIALS AND METHODS

This research was performed at department of agricultural machinery engineering of Agricultural Sciences and Natural Resources University of sari. Automatic solar dryer is designed in order to dry agricultural crops. The mentioned dryer consists of two parts: solar collector and dryer chamber.

Solar collector

The collector which is used in the solar dryer is a flat plat type and made of double layer galvanized sheets (figure 1), between the two layers are insulated with fiberglass in order to prevent heat loss. Absorber plate which is used at the floor of collector was made of 90 × 110 cm foam (With an effective area of approximately 1 square meter). In this research water is used as heat transfer fluid because of its high volumetric heat capacity and thermal conductivity; so 12 aluminum tubes installed onto absorber plate. Tubes length and diameter were 110 cm and 1 cm respectively with 1.03l volumetric capacity. The absorbent plat of the collector painted with black color and finally covered with glass in order to capture more sunlight and increase of heat transfer to the dryer chamber. A 12V hydraulic pump made of Frantic Company, model 4213 is used to transfer hot water with the volumetric flow rate of 2 liters per minute from the solar collector to the drying chamber. Tubes inside the collector, connected to the hydraulic pump with fireproof hoses on one hand and to the condenser box inside the dryer chamber on the other hand. Hydraulic pump transfers cold water from the source of water to the solar collector and then transfers the hot water to the dryer chamber. At this experiment four digital timers was used in order to control the dryer performance accurately and automatic transmission of warm water, one of the timers is for controlling and scheduling the performance of hydraulic pump (Figure 2). A two stroke-timer and an electrical engine with the power of 50 watts and the speed of 800 rpm was used to make an automatic rotational motion of solar collector due to the alteration of solar irradiation angle during daytime. Power needed for all electrical components, supplied with a 12 Volt -12 Amp battery; which is daily recharged by a 30 watts solar panel kit (Figure 1).

Dryer chamber

Dryer chamber is used in this experiment was a cabinet form (Figure 1). Cabinet is made of double layered galvanized sheets and between the two layers are insulated with fiberglass in order to prevent heat loss. The length, width and height of the cabinet are 60, 50 and 95 cm respectively. Dryer chamber consists of 7 (45 ×52 cm) sliding trays with 10 cm distance between them which crops place onto it. The bottom of trays was made of metal tour, in order to better circulation of warm air. The entire space inside the drying chamber painted with fireproof paint in order to prevent corrosion due to the high temperature and humidity. Also a blower fan was installed inside the dryer to uniform the tempe and to remove the products moisture. Two valves applied in order to fresh air entrance and removal of humid air at the bottom and the top of the dryer chamber respectively. In order to transfer hot water from the solar collector, the condenser of a typical refrigerator with 1 horsepower was used inside the dryer chamber. Condenser is a cubic chamber with 52 aluminum tubes which are pressed together in a spiral form, the length and the diameter of tubes are 40 and 0.8 cm respectively with 1.04l volumetric capacity. 30 seconds
needed to completely displace the water inside the collector with considering the volumetric capacity of the aluminum tubes inside the solar collector (approximately 1 Liter) and volumetric flow rate of hydraulic pump, so the timer of the pump was set to stay on for 30 seconds.

In this research, the effects of setting three times on the pump’s timer (5, 10 and 15 minute) and the 4 environmental temperature levels (24, 28, 32 and 36 degree Celsius) were investigated on the performance of solar collector and the solar dryer. The parameters were the inside temperature of the collector, maximum and minimum temperature of the dryer chamber which were measured with a laser thermometer. The collected data evaluated with a factorial test in a completely randomized block design with 12 treatments and three replications and the treatments mean values are analyzed statistically and compared by Duncan test with SAS software.

Figure 1. Components used in solar dryer

Figure 2. Components used in solar collector
RESULTS AND DISCUSSION

The variance analysis results, including main and reciprocal effects pump’s timer (TP) and environmental temperature (TE) to the inside temperature of the collector, maximum and minimum temperature of the dryer chamber inner part are mentioned (table 1). The results show the effect of environmental temperature to the temperature inside the collector, maximum and minimum temperature of the dryer chamber has a significant difference at 1% probability level and also the effect of time changes at pump’s timer to the maximum and minimum temperature of the dryer chamber shows significant difference at 1% probability level too. While it does not show significant difference at the Temperature inside the collector and also the reciprocal effect of these two factors (TP×TE), does not show significant effect at none of the measured parameters either. Table 2 and 3 indicates, the compare between the mean values of maximum and minimum temperatures of dryer chamber at different levels of environmental temperatures and different times adjusted to pump’s timer respectively. According to the table 2, at all levels of timer setting, the maximum temperature inside of dryer chamber rises with the increase in environmental temperature. Also with increasing at time, adjusted to pump’s timer at different levels of environmental temperatures, maximum temperature of dryer chamber rises, so 68.03ºC for maximum temperature, at the environmental temperature of 36ºC and the time of 15min and 29.96ºC for minimum level, at the environmental temperature of 24ºC and 5min were obtained. According to the table 3, the minimum temperature of the dryer chamber rises, with increasing of environmental temperature at all levels of times for pump and also this table indicates 56.70ºC is the upper level of minimum temperature at the environmental temperature of 36ºC and 10 minutes for pump. And 25.73 is the lower level at 24ºC of environmental temperature and 15 minutes. It is interesting to note that the dryer chamber upper level for maximum temperature and the lower level for minimum temperature is obtained at 15 minutes. This indicates there is a high temperature fluctuation at dryer chamber.

Table 2. Comparison of the mean values of the maximum temperature of dryer chamber with different environmental temperature and times adjusted in pump’s timer

<table>
<thead>
<tr>
<th>Environmental temperature (°C)</th>
<th>Time adjusted in pump’s timer (minutes)</th>
<th>Mean value</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>10</td>
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<tr>
<td>24</td>
<td>29.96</td>
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<tr>
<td>28</td>
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<td>32</td>
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<tr>
<td>36</td>
<td>59.16</td>
<td>65.30</td>
</tr>
<tr>
<td>Mean value</td>
<td>45.99</td>
<td>50.60</td>
</tr>
</tbody>
</table>

Means which are shown by uppercase and lowercase letters indicate out-group and in-group comparisons respectively. Shared letters indicate means which are not significantly different. (Minitab-Tukey)

REFERENCES