Investigation of Thermal Efficiency of the Double Pass Oscillating Bed Solar Dryer

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ABSTRACT

Solar energy is abundant and more useful for various applications like power productions, battery charging and drying food product etc. The aim of the project is to develop a solar dryer for drying of agricultural produce like paddy, sunflower seeds and maize for improve their quality. In olden days open Sun drying is the most common method used to preserve agricultural produce in most countries. But it has some problem like unprotected from rain, wind-borne dirt and dust, infestation by insects etc. Some of the problems associated with open-air sun drying can be solved in this new solar dryer. A typical solar dryer comprises two major components viz, a solar collector and a drying chamber. In the present work, a double-pass solar flat plate collector is used to produce hot air and this hot air is supply to two pass oscillating-bed drying chamber through centrifugal blower for drying of agricultural produce. Many Drying test has been conducted using this solar dryer. The drying rate, drying efficiency and pick up efficiency are calculated. From the result, some suggestions are given to improve the efficiency of this solar dryer.

Keywords--- Drying, Solar energy, PV

I. INTRODUCTION

Energy is one of the major inputs for the economic development of any country. In the case of developing countries, the energy sector assumes critical importance in view of ever increasing energy needs, repairing huge investments to meet them.

There are two kinds of energy: non-renewable energy and renewable energy. Non-renewable energy sources are nothing but conventional fossil fuels such as coal, oil and gas, which are likely to deplete with time. Renewable energy is the energy obtained from sources that are essentially inexhaustible, such as sun and wind.

Due to scarcity of petroleum and coal, researchers all around the world focus their attention on the new sources of energy, like renewable energy resources. Solar energy, wind energy, biogas and different thermal and hydro sources are all renewable energy resources. A renewable energy system converts the energy found in sunlight, wind, falling-water, se-waves, geothermal heat, or biomass into a form, we can use such as heat or electricity. Another important feature of renewable energy is that it can be used without the release of harmful pollutants. Renewable energy is also known as non-conventional energy. Renewable energy sources are essentially flows of energy unlike the fossil and nuclear fuels which are considered stocks of energy.

Renewable energy can play a key role in creating a clean, reliable energy future, in the generation of wealth and also a significant component in the economic development (Dincer and Dost (1997)). The benefits are many and varied, including a cleaner environment. The developing worldwide shortage of petroleum emphasizes the need for alternative energy sources that are both inexpensive and clean. Among possible alternative energy sources and the most pollution-free, limitless source is solar energy. The energy from the sun can be used for several useful purposes such as producing electricity, drying of agricultural produce and products (Moon et al. (1981), Hsieh and Coldewey (1974)).

1.1 SOLAR ENERGY

Solar Energy Defined

Solar energy refers to the conversion of the sun’s rays into useful forms of energy, such as electricity or heat. The amount of solar radiation a location receives depends on a variety of factors including geographic location, time of day, season, local landscape, and local weather. Because of our location in North Carolina, we have excellent solar resources.

Solar energy has experienced an impressive technological shift. While early solar technologies consisted of small-scale photovoltaic (PV) cells, recent
technologies are represented by solar concentrated power (CSP) and also by large-scale PV systems that feed into electricity grids. The costs of solar energy technologies have dropped substantially over the last 30 years.

The rapid expansion of the solar energy market can be attributed to a number of supportive policy instruments, the increased volatility of fossil fuel prices and the environmental externalities of fossil fuels, particularly greenhouse gas (GHG) emissions.

**How Solar is used to Create Energy**

When converted to thermal (or heat) energy the solar energy can be used to:

- **Heat water** – for use in homes, buildings, or swimming pools.
- **Heat spaces** – inside homes, greenhouses, and other buildings.
- Solar energy can also be converted into electricity:
  - **Photovoltaic (PV)** or solar cells change sunlight directly into electricity.
  - **Concentrating Solar Power Plants** generate electricity by using the heat from solar thermal collectors to heat a fluid which produces steam. The steam is used to power a turbine and generate electricity.

1.2 **SOLAR DRYER**

Due to the current trends towards higher cost of fossil fuels and uncertainty regarding future cost and availability, use of solar energy in food processing will probably increase and become more economically feasible in the near future. Solar dryers have some advantages over sun drying when correctly designed.

They give faster drying rates by heating the air to 10-30°C above ambient, which causes the air to move faster through the dryer, reduces its humidity and deters insects. The faster drying reduces the risk of spoilage, improves quality of the product and gives a higher throughput, so reducing the drying area that is needed. However care is needed when drying fruits to prevent from rapid drying, which will prevent complete drying and would result in case hardening and subsequent mould growth. Solar dryers also protect foods form dust, insects, birds and animals. They can be constructed from locally available materials at a relatively low capital cost and there are no fuel costs. Thus, they can be useful in areas where fuel or electricity are expensive, land for sun drying is in short supply or expensive, sunshine is plentiful but the air humidity is high. Moreover, they may be useful as a means of heating air for artificial dryers to reduce fuel costs.

The moisture content in freshly harvested agricultural produce should be brought down so as to store the produce such as non-parboiled paddy grains and maize for uses in future and to increase the oil content in produce such as sunflower seeds and ground nuts.

A solar dryer uses a solar energy collector for heating the air. The drying system has separate areas for collection of solar energy and for drying producer. The heat is transferred from the air heater to the drying chamber either by free convection or forced circulation of air. Collectors such as flat plate collectors, concentrating collectors are usually employed in harnessing the solar energy which in turn is used in dryers. A flat plate solar collector can be used in solar dryers for supplying hot air to dry agricultural produce efficiently and economically during sunny as well as overcast periods.

II. EXPERIMENTAL SETUP

2.1 **INTRODUCTION**

The oscillating-bed solar dryer consists of several components and the construction details are explained in this chapter. The description and the working of the components are discussed followed by the specification of the instruments used. The methodology of conducting the experiments is also explained.

2.2 **EXPERIMENTAL SET-UP**

The present experimental set-up of an oscillating-bed solar dryer is explained in the following sections.

Figure 5. Experimental setup
2.3 LIST OF COMPONENTS

- Double-pass flat plate collector
- An insulated centrifugal blower
- Double pass oscillating-bed
- Mechanism used for oscillation

2.3.1 DOUBLE-PASS FLATE PLATE COLLECTOR

In the double-pass flat plate collector first stream of the air passes between the glass cover and absorber plate and second stream of the air passes between the absorber plate and the bottom plate. It consists of an aluminum sheet which is called as absorber plate. It is painted in dull black color on both sides. A transparent glass cover is placed above the absorber plate, and a galvanized iron sheet used as bottom plate is placed below the absorber plate. Figures 5.2 show a view of the double-pass solar flat plate collector.

![Figure 6. Air heater](image)

The bottom plate is insulated with ceramic wool and wooden plank to minimize the bottom heat loss. A wooden frame is used not only to support the three plates but also to provide an air passage duct too. The inside of the wooden frame is coated with insulating paint in order to minimize the side heat loss. An insulated trapezoidal duct at the collector outlet connects the blower inlet through pipe connector.

![Figure 7. A view of double-pass flat plate collector](image)

The collector is supported by a metal frame with a provision to tilt it at any desired angle with respect to the ground. Figure 3.4 shows a photo gallery of components of the double-pass solar flat plate collector.

2.3.2 INSULATED CENTRIFUGAL BLOWER

The insulated blower is used to circulate the hot air from the collector to the drying chamber. A pipe connector is also used to connect the blower outlet with the bed inlet through a rubber bellow. The rubber bellow is used to keep the blower free from oscillating motion of the bed.

2.3.3 DOUBLE PASS OSCILLATING BED

The two dimensional sectioned view of the oscillating-bed. It consists of a hopper, a perforated tray, bed, and flat plate outlet called produce outlet at the trailing end of the bed. The feeder is a hopper mounted over the bed at the leading one end of the bed for storing and supplying the agricultural produce continuously through a bottom slot over the perforated tray during oscillation of the bed.

The opening of the feeder at the bottom of the hopper can be changed using adjustable metal straps to change the supply of the agricultural produce. The perforated tray is made of metal steel plate having number of small holes to allow the hot air from the bed to penetrate through the holes for drying of agricultural produce.
The perforated tray is mounted on the wooden frame with the angle of 10°. The tilted perforated tray is used to help the movements of the agricultural produce. The bed is a wooden box with the top side gets opened to locate the perforated tray.

The flat plate is a small sheet metal outlet mounted at the trailing end of the bed used to collect the dried agricultural produce. There are four flat belts used to suspend the bed from the bed frame for the purpose of the oscillation. An oscillating system consists of a bed motor, V-pulley, V-belt, and an eccentric cam. The eccentric cam is mounted on a shaft with a pulley driven by a bed motor through V-belt. A connecting rod is used to connect the bed with the eccentric cam. The oscillating system is designed to oscillate the bed with the frequencies of 2.5Hz. The bed frame is used to provide the support for oscillating system and for the bed suspension. In this study, an attempt was made to enhance the moisture removal from the agricultural produce during drying. The hot air was supplied at the bottom of the perforated tray on the bed.

During the travel of agricultural produce along the perforated tray the hot air is move from bottom of oscillating bed to the top of the oscillating bed. That time hot air picked up the moisture from the agricultural produce and the hot air is losing its sensible heat. Hence, the low temperature gradient occurred across the lay.

### 2.3.4 OSCILLATING MECHANISM

This arrangement consisting of two number of 20mm shafts of length 350mm, two round plates of diameter 120mm, two number of 20mm plummer block, a connecting rod and a hollow shaft of 20mm diameter, a V-belt, V-pulley and a clamp support. The block diagram of the oscillating mechanism.
2.4 WORKING OF THE OSCILLATING MECHANISM

shows three dimensional view of oscillating mechanism. The quarter HP motor is used to drive the V- pulley of 30mm diameter. The shafts of 350mm length are supported on the frame through plummer block bearings. The eccentric cam is mounted at the two free ends of the shafts as shown in the figure. When the motor is driven, the eccentric cam moves the connecting rod back and forth. Hence the wooden bed dryer oscillates through clamp made between it and the connecting rod.

III. PERFORMANCE GRAPHS

GRAPH BETWEEN TIME AND SOLAR ISOLATION

![Solar isolation(W/m2)](image)

GRAPH BETWEEN TIME AND TEMPERATURES

![Temperature(K)](image)

IV. PERFORMANCE CALCULATION FORMULA

4.1.1 HEAT RECEIVED BY THE SOLAR AIR HEATER ($Q_{ah}$)

$$Q_{ah} = m'_{a1} \times C_{pa} (T_3 - T_a) \quad \text{1}$$

$$m'_{a1} = \rho_a \times A \times V_{a1} \quad \text{2}$$
\[ A = \pi d^2 / 4 \]

### 4.1.2 EFFICIENCY OF AIR HEATER (\( \eta_{ah} \))

\[ \eta_{ah} = Q_{ah} \times 100 / (A_{ah} \times G_s) \]  \[3\]

### 4.1.3 INITIAL MOISTURE CONTENT (\( M_i \))

\[ M_i = (w_d - w_o) / w_o \]  \[4\]

### 4.1.4 FINAL MOISTURE CONTENT (\( M_f \))

\[ M_f = (w_d - w_t) / w_d \]  \[5\]

### 4.1.5 AMOUNT OF HEAT LOST BY THE AIR IN THE DRYING CHAMBER (\( Q_{ld} \))

\[ Q_{ld} = m_{a2} \times C_{pa} \times \left( T_4 - T_6 \right) \]  \[6\]

### 4.1.6 DRYING CHAMBER EFFICIENCY (\( \eta_{dc} \))

\[ \eta_{dc} = (w_d - w_t) \times h_{fg} \times 100 / m_{a2} \times (h_o - h_i) \times t \]  \[7\]

### V. MODEL CALCULATION

#### (Heat received by the solar air heater (\( Q_{ah} \)))

\[ Q_{ah} = m_{a1} \times C_{pa} \times (T_3 - T_a) \]  \[1\]

\[ m_{a1} = \rho_a \times A \times V_{a1} \]  \[2\]

From HMT data book page no.34: \( T_3 = 343 K \), \( \rho_a = 1.01 \text{ kg/m}^3 \)

\[ A = \pi d^2 / 4 \]

\[ \frac{m_{a1} \times V_{a1}}{4(0.075)^2} = 0.0044 \text{ m}^2 \]

\[ V_{a1} = 26.08 \text{ m/s} \]

\[ m_{a1} = 1.010\times0.0044\times26.08 = 0.0289222 \text{ kg/s} \]

\[ C_{pa} = 1.005 \text{ kJ/kg.K} \]

\[ T_a = 325 \text{ K} \]

Therefore,

\[ Q_{ah} = 0.0289222\times1.005(343-325) = 0.52320257 \text{ kW} \]

#### Efficiency of solar air heater

\[ \eta_{ah} = Q_{ah} \times 100 / (A_{ah} \times G_s) \]  \[3\]

### 4.1.7 DRYING CHAMBER EFFICIENCY (\( \eta_{dc} \))

\[ \eta_{dc} = (w_d - w_t) \times h_{fg} \times 100 / m_{a2} \times (h_o - h_i) \times t \]  \[7\]

From steam table the table no: 1 at \( T_4 = 331 K \)

\[ h_{fg} = 2338.9 \text{ kJ/kg} \]

\[ t = 100 \text{ s} \]

\[ \eta_{dc} = \frac{0.0319\times100}{0.1509\times1.005\times3\times100} = 49.5\% \]

### VI. SUMMARY AND CONCLUSION

#### 6.1 SUMMARY

A survey was made from the published literature pertinent to the drying of agricultural products using the solar energy indicating a solar dryer which facilitates to both oscillate and tilt the bed, on which the agricultural products are usually spread, which is kept for drying. In order to supply hot air for drying, a double-pass flat plate solar air heater would be used attached to the drying chamber. One such solar dryer was fabricated and non – par boiled paddy were dried. The bed of this solar dryer was tilted at 2.5° with respect to horizontal plane and the bed can be oscillated.

The hot air was fed into the base of the bed so that when paddy passes through the tray, the hot air absorbs away the moisture from the paddy and reduces its moisture content this process was depicted.

#### 6.2 CONCLUSIONS

The following are the major conclusions that are drawn from the model:
1. The double pass air preheater is used so that maximum amount of heat is gained by the air before being fed into the blower.
2. The double pass tray is used so that pre-drying is done in the first tray due to direct heat radiation from the sun and while in the second tray hot air from the bottom is used for drying the paddy further.

VII. REFERENCES


[10] Experimental study on the combined effects of inclination angle and insert devices on the performance of a flat-plate solar collector by Gurveer Sandhu, Kamran Siddiqui, Alberto Garcia