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An Experimental Study to Select Optimum Heat Storage Materials Bed Thickness and Optimum Air Velocity for a Designed Solar Dryer

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ABSTRACT : *Solar drying is one of the important applications of solar energy which is used to remove moisture from the agricultural products. This study was conducted to select the optimum heat storage materials bed thickness and optimum air velocity for a designed solar dryer of 0.5 m^2 drying chamber area and 0.5 m^2 heat storage cabin area. Experiments were conducted with heat storage material bed thickness of 20 mm, 30 mm and 40mm with air velocity of 2 m/s, 4 m/s and 6 m/s. From the experimental results it has come to conclusion that, 20 mm is the optimum bed thickness and 4 m/s is the optimum velocity. Some of the important parametersto be considered for selecting heat storage materials for the solar drying applications are also briefly discussed in this study.*

Keywords – *Solae energy, Solar dryer, Heat storage materials, Solar drying, Gravels heat storage.*

I. Introduction

Now days due to rapid increase in population, food demand of world increased significantly. This increase in food demand of the world can be meeting by bringing more land under agriculture to grow food crops and another alternative is to reduce post harvesting losses [1]. Solar drying is one of the important applications of solar energy which helps to remove moisture from the products like fruits and vegetables. Use of solar dryers in agricultural sector helps to reduce post harvesting losses.

The common method used for drying of agricultural product is to expose the products directly to sun light and this is called as natural sun drying or open sun drying. The main advantages of this method are simple and economical but this method of drying is having many serious disadvantages like no control over the drying process, product may over dried, sudden rain may cause damages, possibility of attack by birds and animals, dust and un wanted particles may mix with the products [2]. Solar dryers are the better alternative to overcome the disadvantages of open sun drying. Mainly solar dryers are three types namely direct mode dryer, indirect mode dryers and mixed mode dryers. In direct mode dryers, sun's radiations are allowed to incident directly the products to be dried through the glass cover. In indirect mode dryers, sun's radiations are not allowed to incident directly on products, a separate collector is used to absorb heat energy from the sun's radiation and part of this absorbed heat energy is transfer to the incoming air from the atmosphere and then air is allowed to flow in to the drying chamber. For photo sensitive products this type of dryer is used. In mixed mode dryers, sun's radiations are allowed to incident directly on products to be dried through glass cover and at the same time hot air is passed to the drying chamber from a separate collector (Air heater). Figure 1 given below represents the line diagram of the three types of dryers. Selection of particular type of solar dryer depends upon the parameters like type and shape of the product, area required, drying temperature and relative humidity [3].

In recent years many developments of solar dryers have been taken place in many countries of the world. Some important developments are explained summarised in this section. Researchers [4,5] developed direct mode solar dryers for drying of pepper and ground nuts by using low cost materials which are available at local market. A direct mode dryer with an arrangement to vary the glass cover inclination angle with seasons is also reported [6]. Similar types of dryers are also developed for drying of fishery products [7]. These type dryers are suited for temperature range of 40^0 C – 60^0 C [8].Indirect mode solar dryers are developed for drying applications of different agricultural products and in these dryers; researchers have attempted to use different collector materials (Air heaters). Some of the collector materials (Air heaters) reported in the literature are gravels [9], evacuated tubes [10], sand [11]. For higher drying rates mixed mode dryers are preferable. Researchers [12, 13, 14] developed mixed mode dryers for drying of products like yam, chillies and cuminum grains. A typical cylindrical dryer [15] was developed for drying of 70 kg bean crop. Numerical analysis [16] and exergetic [17] analysis is also carried out by the researches on dryers in order to understand the drying process.

The main objective of this study is to select the optimum bed thickness and the velocity for a given designed drying system.

II. METHODOLOGY

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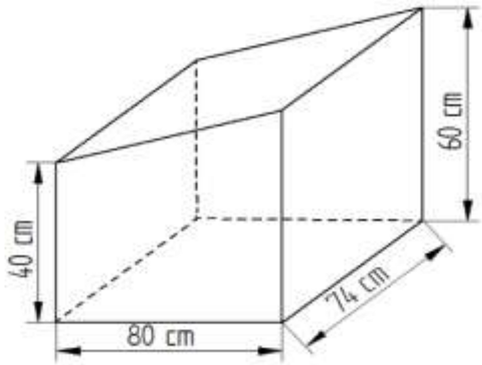

Figure 2.1 Dimensional details of dryer cabin

The complete experimental setup was fabricated by using low cost materials which are available in local market. Dryer cabin is made of Galvanized Iron of 5 mm thickness, inlet and outlet vents were provided for air circulation. Two iron mesh trays were used to keep products to be dry inside the dryer. The thermocol insulation of 20 mm thickness is used at all sides and bottom of the dryer cabin to avoid conduction heat losses to the surroundings. Fig.1.1 represents the dimensional specifications of dryer cabinHeat storage material is made of 12 mm thick play-wood and a 5 mm thick transparent glass cover was used. Granite stones were crushed into cylindrical shape with 20 mm diameter and filled up to the bed thickness of 20 mm along the length of

Experiments were conducted under the metrological conditions of Ujire, Karnataka, India(12.9955° N, 75.3281° E) on heat storage cabin with different bed thickness and also with different air velocity to find optimum bed thickness and velocity for given designed dryer. The figure 4 represents the pictorial diagram of heat storage materials cabin. Bed thickness used were 20 mm, 30 mm and 40mm and velocities used were 2 m/s, 4 m/s and 6 m/s. Totally 9 trails were conducted with varying velocity and thickness. Experiments were

the cabin. Figure 2 represents the dimensional specifications of heat storage material cabin. For optimum performance, heat storage cabin (Air heater) dimensions were selected based on the length (L) to width (W) ratio as 1.5 (L/W = 1.5) and dryer cabin length and width were same as heat storage cabin dimensions [18]. The fig1.2 shows the dimensional specifications of heat storage cabin.

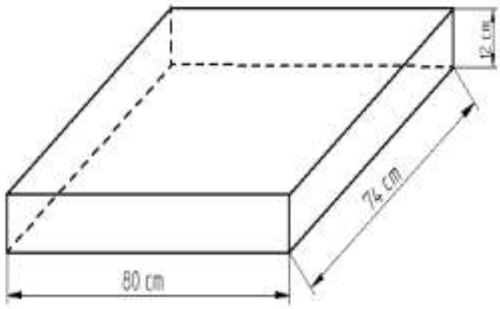

Figure 2.2 Dimensional specification of heat storage material cabin

The dryer cabin and heat storage material cabin are connected by using hose pipes. A blower is used for air circulation. Fig. 2.3 represents the schematic diagram of given experimental setup.

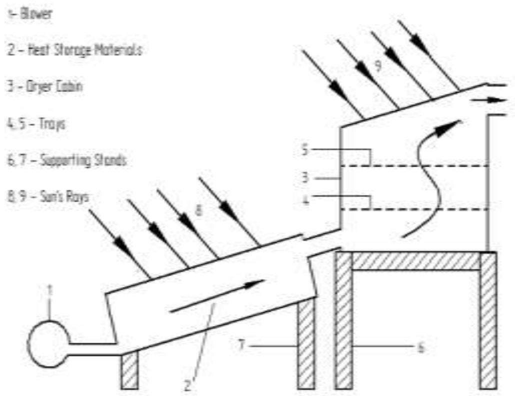

Figure 1.3 Schematic diagram of experimental setup

started at 9:00 am and stopped at 5:00 pm daily. For every one hour interval readings were recorded. Air blower is provided with a regulator to vary the velocity of air and with the help of anemometer velocity of air at blower exit was measured and then blower is fitted to the experimental setup, temperature was measured with thermometer and solar radiation intensity was measured with pyranometer.

In this paper, purpose of representing complete drying system diagram is to give an idea about drying system which is used with heat storage materials for drying applications in future. Therefore discussion is not made regarding dryer cabin and its performance. Fig. 2.4

Figure 2.4 Pictorial view of experimental setup

III. RESULTS AND DISCUSSIONS

In this section obtained results are discussed with the aid of graphs. Fig. 3.1 shows the values of outlet temperature for the bed thickness of 20 mm with respect to time. It is observe that, outlet temperature increases gradually as the intensity of solar radiation increases and decreases after reaching a peak value. Maximum temperature recorded were 57 ^{0}C for air velocity of 2 m/s, 65 ^{0}C for air velocity of 4 m/s and 53 ^{0}C for air velocity of 6 m/s. Fig 3.2 represents the values of temperature for the bed thickness of 30 mm. Here a similar variation in outlet temperature of air with intensity of solar radiation was observed. Maximum outlet temperature obtained were 54 ^{0}C for 2 m/s air velocity, 58 ^{0}C for air velocity of 4 m/s and 51 ^{0}C for air velocity of 6 m/s. Fig.3.3 represents the values corresponding to 40 mm bed thickness. Maximum temperature outlet temperature of air recorded was 54 ^{0}C for 2 m/s, 57^{0}C for the velocity of 4 m/s, and 53 ^{0}C for 6 m/s.

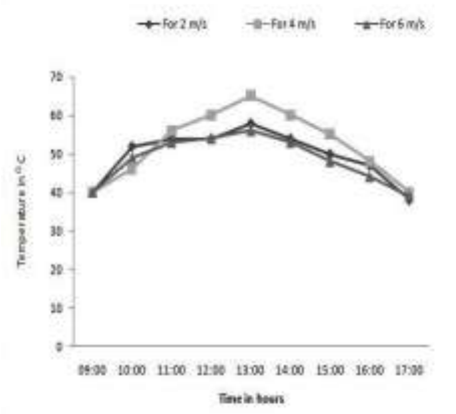

Figure 3.1 Time V/S Temperature for 20 mm bed thickness

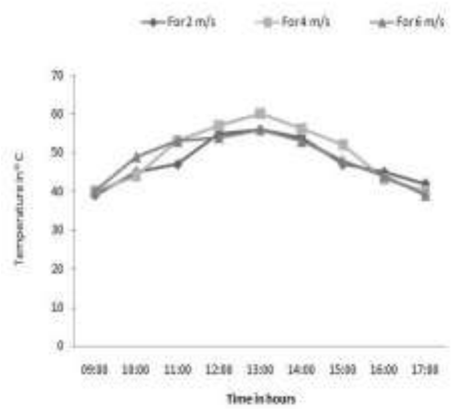

Figure 3.2 Time V/S Temperature for 30 mm bed thickness

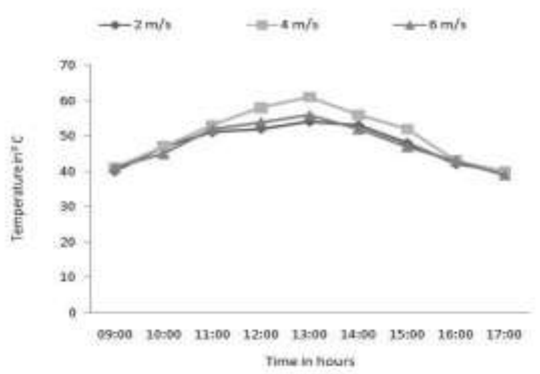

Figure 3.3 Time V/S Temperature for 40 mm bed thickness

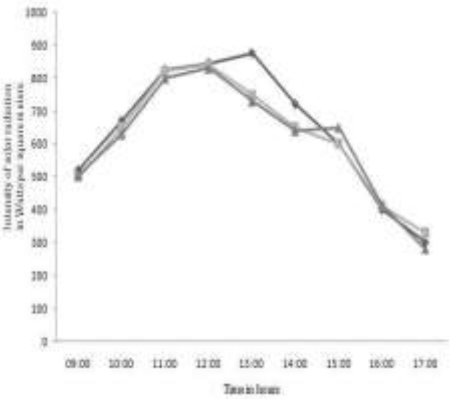

Figure 3.4 Time v/s Intensity of solar radiations

Figure 3.4 gives the spectral distribution of solar radiations during the experiments. It is observe that, intensity of solar radiations gradually and reaches peak value then start decreasing gradually. Maximum value of solar radiations recorded was 840 W/m^2 and minimum was 280 W/m^2.Variation in outlet temperature of air fallows the same nature of variation as solar radiation fallows. From the above obtained results, 20 mm bed thickness is selected as optimum bed thickness for given designed dryer and 4 m/s velocity as optimum velocity. From the values of experimental data it is noted that, amount heat energy gained by the air is depends more on intensity of solar radiation. This is due to reason that when solar more amount of solar radiation incident on heat storage materials, it absorbs it and transfer part of this absorbed energy to the air passing over the surface of the materials. Properties of heat storage materials plays an important role in absorbing heat from the sun's rays and transferring absorbed heat to the air flowing over the surfaces of heat storage materials. Some of the important properties should be consider while selecting heat storage materials are; thermal conductivity, thermal diffusivity, density and specific heat. Along with above mentioned properties temperature range of application, availability and cost are the other important parameters to be considered. The maximum allowable temperature for most of the agricultural products is below 75 ^{0}C and it is possible to attain this temperature by using stones (Crushed stones).

IV. CONCLUSIONS

The main objective of this study was to select the optimum heat storage materials bed thickness and optimum air velocity. It is concluded from the obtained results that for a given drying system of 0.5 m^2 drying cabin area and 0.5 m^2 heat storage materials cabin area, optimum bed thickness is 20 mm and 4 m/s. For most of the agricultural products maximum allowable temperature is below 70 ^{0}C and it is possible to achieve this temperature by using stones (crushed stones) as heat storage materials. The important properties to be considered for selecting heat storage materials for drying applications are thermal conductivity, thermal diffusivity, and density, temperature range of application, availability and cost.

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