DESIGN AND FABRICATION OF SOLAR CONVECTION GRAIN DRYER

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Abstract: The solar drying system utilizes solar energy to heat up air and to dry any grain substance loaded, which is beneficial in reducing wastage of agricultural product and helps in preservation of agricultural product. Based on the limitations of the natural sun drying e.g. exposure to direct sunlight, liability to pests and rodents lack of proper monitoring, and the escalated cost of the mechanical dryer, a solar is therefore developed to cater for this limitation. This project presents the design, construction and performance of a mixed-mode solar dryer for grain preservation. In the dryer, the heated air from a separate solar collector is passed through a grain bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls and roof. The results obtained during the test period revealed that the temperatures inside the dryer and solar collector were much higher than the ambient temperature during most hours of the day-light. The dryer exhibited sufficient ability to dry grain items reasonably rapidly to a safe moisture level and simultaneously it ensures a superior quality of the dried product.

Keywords: Solar Convection, Grain Dryer, Solar Drying.

I. INTRODUCTION

Drying is one of the methods used to preserve food products for longer periods. The heat from the sun coupled with the wind has been used to dry food for preservation for several thousand years. Solar thermal technology is a technology that is rapidly gaining acceptance as an energy saving measure in agriculture application. It is preferred to other alternative sources of energy such as wind and shale, because it is abundant, inexhaustible, and non-polluting. Solar air heaters are simple devices to heat air by utilizing solar energy and it is employed in many applications requiring low to moderate temperature below 80°C, such as crop drying and space heating. Drying is the oldest preservation technique of agricultural products and it is an energy intensive process. High prices and shortages of fossil fuels have increased the emphasis on using alternative renewable energy resources. Drying of agricultural products using renewable energy such as solar energy is environmental friendly and has less environmental impact. Different types of solar dryers have been designed, developed and tested in the different regions of the tropics and subtropics. The major two categories of the dryers are natural convection solar dryers and forced convection solar dryers. In the natural convection solar dryers the airflow is established by buoyancy induced airflow while in forced convection solar dryers the airflow is provided by using fan operated either by electricity/solar module or fossil fuel. Now the solar dryer designed and developed for and used in tropics and subtropics are discussed under two headings.

II. LITERATURE REVIEW

Crop drying is the most energy consuming process in all processes on the farm. The purpose of drying is to remove moisture from the agricultural produce so that it can be processed safely and stored for increased periods of time. Crops are also dried before storage or, during storage, by forced circulation of air, to prevent spontaneous combustion by inhibiting fermentation. It is estimated that 20% of the world's grain production is lost after harvest because of inefficient handling and poor implementation of post-harvest technology, says Hartman's (1991). Grains and seeds are normally harvested at a moisture level between 18% and 40% depending on the nature of crop. These must be dried to a level of 7% to 11% depending on application and market need. Once a cereal crop is harvested, it may have to be stored for a period of time before it can be marketed or used as feed. The length of time cereal can be safely stored will depend on the condition it was harvested and the type of storage facility being utilized. Grains stored at low temperature and moisture contents can be kept in storage for longer period of time before its quality will deteriorate. Some of the cereals which are normally stored include maize, rice, beans.

Solar drying may be classified into direct and indirect solar dryer. In direct solar dryers the air heater contains the grains and solar energy which passes through a transparent cover and is absorbed by the grains. Essentially, the heat required for drying is provided by radiation to the upper layers and subsequent conduction into the grain bed. However, in indirect dryers, solar energy is collected in a separate solar collector (air heater) and the heated air then passes through the grain bed, while in the mixed-mode type of dryer, the heated air from a separate solar collector is passed through a grain bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls or the roof.

Energy is important for the existence and development of human kind and is a key issue in international politics, the economy, military preparedness, and diplomacy. To reduce the impact of conventional energy sources on the environment, much attention should be paid to the development of new energy and renewable energy resources. Solar energy, which is environment friendly, is renewable and can serve as a sustainable energy source.

Hence, it will certainly become an important part of the future energy structure with the increasingly drying up of the terrestrial fossi l fuel. However, the lower energy density and seasonal doing with geographical dependence are the major challenges in identifying suitable applications using solar energy as the heat source. Consequently, exploring high efficiency solar energy concentration technology is necessary and realistic.

Solar energy is free, environmentally clean, and therefore is recognized as one of the most promising alternative energy recourses options. In near future, the large-scale introduction of solar energy systems, directly converting solar radiation into heat, can be looked forward. However, solar energy is intermittent by its nature; there is no sun at night. Its total available value is seasonal and is dependent on the meteorological conditions of the location. Unreliability is the biggest retarding factor for extensive solar energy utilization. Of course, reliability of solar energy can be increased by storing its portion when it is in excess of the load and using the stored energy whenever needed. Solar drying is a potential decentralized thermal application of solar energy particularly in developing countries. However, so far, there has been very little field penetration of solar drying technology.

III. DESIGN APPROACH AND METHODOLOGY

Solar drying refers to a technique that utilizes incident solar radiation to convert it into thermal energy required for drying purposes. Most solar dryers use solar air heaters and the heated air is then passed through the drying chamber (containing material) to be dried. The air transfers its energy to the material causing evaporation of moisture of the material.

In the process of drying, heat is necessary to evaporate moisture from the material and a flow of air helps in carrying away the evaporated moisture. There are two basic mechanisms involved in the drying process: the migration of moisture from the interior of an individual material to the surface, and the evaporation of moisture from the surface to the surrounding air.

3.1 DESIGN OF SOLAR COLLECTOR

Assumptions:-

Diameter of sun = 1.4×10^9 m

Radius of sun = 0.7×10^9 m

Mean distance from earth = 15×10^{10} m

Radius of earth, $r_e = 6.4 \times 10^6$ m

Temperature of the sun , T = 5750 K

Total energy emitted by Sun, $E_b = \sigma A T^4$

$= 3.816 \times 10^{26}$ Watt.

Emission received on earth = $(3.816 \times 10^{26}) / (4\pi (15 \times 10^{10})^2)$

$= 1349.6$ Watt/m^2

Energy lost in atmosphere = 10%

So available energy = 90% of 1349.6 watt/m^2

= 1215 Watt/m^2.

Assuming diffuse radiation = 30% of 1215 Watt/m^2

= 364.5 Watt/m^2

Total radiation receiving on earth = 1215 + 364.5

= 1579.5 Watt/m^2

Area of collector = $0.5 \times 0.5 = 0.25$m^2

Energy received by collector = $1579.5 \times 0.5 \times 0.5 \times \cos 45^o$

= 279.13 = 300 Watt.

Ambient air temperature = 30°C

Heated air temperature = 50° "m" be the mass flow rate of air carryingheatb of collector.

So,

$0.3 = m \times 1.005 \times (50-30)$

Or, m = 0.0639 kg/ sec

3.2 DESIGN OF GRAIN DRYER AND CALCULATION OF FAN POWER

Assumptions:

Height = 0.7 m

Radius = 0.2 m

Volume = $\pi r^2 h$

= 3.14× $(0.2)^2$×0.7

= 0.087964 m^2

Ambient air temperature = 30°C

Relative humidity = 70%

Initial moisture content = 18% wet basis

Final moisture content = 12% wet basis

Grain inlet temperature = 30°C

Grain outlet temperature = 40°C

Heated air temperature = 50°C

Exhaust air temperature = 40°C

Latent heat of water vapour = 2257 KJ/ Kg

Wheat density = 615.2 Kg/m^3 for 18% moisture content.

Drying time = 8 hours

Sensible heat of wheat = 0.367 Kcal/ kg

Density of air = 1.13 Kg/ m^3

System is designed for 1Kg capacity.

Air Requirement:

Dry wheat = 1(1-0.12) = 0.88 kg

Intial moisture content = 18% w.b

= (m/(100 - m)) × 100

= (18/(100 - 18)) ×100 = 0.2195× 100

= 21.95 d.b

Final moisture content = (m/(100 - m)) × 100

= (12/(100 - 12)) × 100 = 0.1363 × 100

= 13.63 d.b

So, weight moisture evaporated = 0.88(0.2195 - 0.1363)

= 0.07316 kg

Heat Calculation:

Let mass flow rate be "G" in kg/second.

Heat carried by air = G × 1.005× 8 × 60 × 60 × (50-40)

= 288000 G

Assuming loss of heat as 30%, so heat carried = 70% of 288000 G = 201600 G

Sensible heat of grain = 0.88 × 0.367 × (40 - 30) = 3.2296 kcal

= 13519.10 KJ

Sensible heat of water = 0.88 × 4.2× 10

= 39.96 KJ

Latent heat of water vapour = m × L = 0.07316 × 2257 = 165.122 KJ

Total heat = 13519.10 + 39.36 + 165.122 = 13724.182 KJ

Now,

Heat lost = Heat gained

201600 G = 13724.182

G = 0.06807 kg/sec = 4.0845 kg/min

Calculation Of Fan Power

Humid volume of ambient air = 4.0845 × 0.88 m^3/kg

(0.88 m^3/kg is from psychometric chart at 70% R.H and 50°C DBT)

= 3.594 m^3/min = 127.027 cfm (1 m = 3.280 foot)

Area of dryer = $2\pi rh$

= 2 × 3.14 × 0.2 × 0.7 = 0.8796 m^2

Assuming 50% area to be perforated, so effective area = 50% of 0.8796 m^2

= 0.4398 m^2 = 4.7315 ft^2

Now, air requirement per feet = 127.027 / 4.7315 = 26.846 cfm / ft^2.

Now by **SHEED'S CURVE**

For wheat,

60 cfm /ft^2 = 0.7 inch of water per 1feet grain depth.

1 cfm / ft^2 = 0.7 / 60 inch of water

so, 26.846 cfm / ft^2 = (26.846 × 0.7) / 60 = 0.3132

pressure drop = (0.3132 × 18) / 12 = 0.4698 inch of water.

Assuming 40% pressure drop due to resistance offered by grain.

So, total pressure drop = 1.4× 0.4698 = 0.65774 inch of water = 1.6706 cm of water.

Since density of air = 1.13 kg / m^3

Pressure drop in air column = (1.6706 × 1000) / (100 × 1.13) = 14.784 m.

Horse power required = (Height of air column × air flow rate) / 4500

= (14.784 × 4.0845) / 4500

= 0.01341 H.P

= 10 Watt.

3.3 Material Used

Material used is steel and instead of welding of the parts we used bolts and screws for constructing the project show that it could be easily assembled and disassembled quickly and easily for maintenance. Screws and bolt are of stainless steel.

IV. RESULT AND DISCUSSION

In many parts of the world there is a growing awareness that renewable energy have an important role to play in extending technology to the farmer in developing countries to increase their productivity. Solar thermal technology is a technology that is rapidly gaining acceptance as an energy saving measure in agriculture application. The model fabricated was working satisfactory under the temperature variation of the city. The images of the model fabricated are as follows:

Figure 1

Figure 2

The application of dryers in developing countries can reduce post harvest losses and significantly contribute to the availability of food in these countries. Estimations of these losses are generally cited to be of the order of 40% but they can, under very adverse conditions, be nearly as high as 80%. Natural convection dryers circulate the drying air without the aid of a fan. They are therefore, the most applicable to the rural areas in developing countries.

V. REFERENCES

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