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Design Consideration of Solar Paddy Dryer

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***Abstract*— Rice is one of the major crops being produced in the world and about 70 % of the world populations depend on this crop. So, the need for drying facilities at the site of the rice production is essential if post production losses to be kept to a minimum. Some dryers are run by diesel or gasoline engines and natural source of sun. In this paper, the drying system will be powered by solar energy sources. This paddy dryer is an enclosed unit, so the grain is safe from damage by birds and inserts. In this paper, this indirect chimney dryer is designed to reduce moisture content from 22 % to 14 % (web bulb) for storage. The flat bed dryer design is calculated for 0.5 ton capacity. This prototype dryer design is calculated for 73.5 kg of paddy. And then, solar paddy dryers are analyzed by changing the drying capacity with same chimney height.**

***Index Terms*— Solar dryer, Drying capacity, Collector, Paddy box, Paddy bed.**

1) INTRODUCTION

To improve the farmer's life, it mainly depends on the increasing of rice production and getting of good quality of rice .The use of modern rice production technology can increase production. The rice production processes involved include harvesting, threshing, drying, storing and milling the grain. Improvement in the quality of many farm products is directly related to their drying. In this type of drying, the solar energy from the sun can be efficiently tapped and collected through solar collector. Collectors are generally made of materials with high absorptivity-black bodies. The paddy is dried using solar thermal energy in a cleaner and healthier way. The various types of solar grain dryers are cabinet dryer, tent dryer, chimney dryer, solar rice dryer, forced-air solar grain dryer and AIT solar tunnel dryer. In this paper, the solar grain dryer is used type of chimney dryer. Solar dryers can be made in different sizes and shapes based on the quantity of grain. The sizes and shapes also depend on domestic or commercial use.

2) WORKING PRINCIPLES OF THE DRYER

Solar radiation, both direct radiation from the sun and indirect radiation or diffuse radiation from the sky, passes through the clear substance and warms the air inside the collector, as shown in the figure.1. The matt black substance covering the ground below changes the solar radiation into heat and transfers the heat to the warm air. Since the warm air has a low density, it passes up through the bed of the paddy and the drying starts gradually from the bottom layer into the middle. Solar radiation passes through the clear roof and increases the buoyancy of the moist warm air over the rice bed. The remaining solar radiation directly heats the top layer of paddy and then the middle layer, and in this way drying starts from the top and continues into the middle layer. Hence, the drying in the solar dryer proceeds both from the top and the bottom into the middle layer. Solar radiation absorbed by the black chimney provides a full column of warm air to increase the air flow through the bed by natural convection.

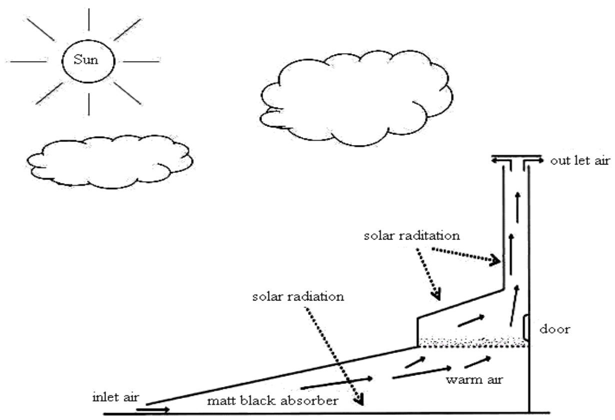

Figure .1. Working Principles of the Dryer

3) DESIGN CONSIDERATION

To carry out design consideration and sizes of the dryer, the design parameters and assumptions summarized in table 1 are used for the design of the paddy dryer. From the conditions and relationships, the values of the design parameters were calculated by using following equations. The result of calculations is summarized in table 2.

i The required energy

The amount of heat required to evaporate the water the drying equation is

$$Q_w = m_w L$$

Where;

Q_w = required energy
m_w = weight of water removed from the paddy
L = specific latent heat of vaporization of water

$$m_w = \text{initial weight} \times \left(\frac{Mo - Mf}{100 - Mf} \right)$$

ii Size of the paddy box

$$\text{Half ton of paddy volume} = \frac{\text{mass}}{\text{density}}$$

$$\text{The floor area of the paddy bed} = \frac{\text{volume}}{\text{depth of the paddy bed}}$$

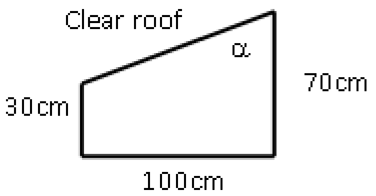

Figure .2. Dimension of the Paddy Box

iii Depth of the paddy bed

The convection of air through the rice bed is caused by a pressure drop across. It is resulting from the difference between the density of the relatively cool ambient air and the warm air inside the dryer, figure.3 shows the symbols in calculation of rice bed thickness of dryer.

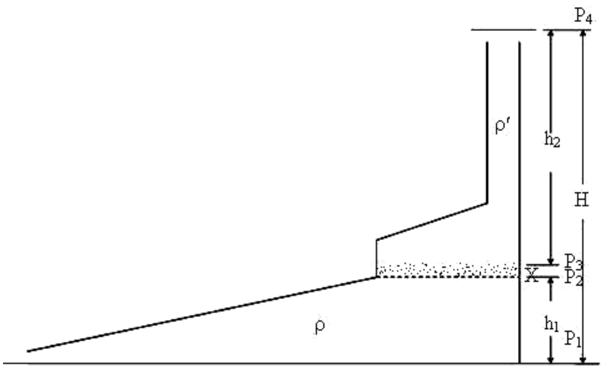

Figure .3. Symbols in Calculation of Rice Bed Thickness of Dryer

Where:

ρ = density of ambient air, 1.1514 kg/m^3

ρ' = density of warm air inside the dryer, 1.1014 kg/m^3

h_1 = height of false floor

h_2 = height from chimney cap to rice bed

H = height of chimney from ground level

P_1 = air pressure at ground level

P_2 = air pressure under rice bed

P_3 = air pressure over rice bed

P_4 = air pressure at air outlet

X = thickness of rice bed

V = the air velocity entering and leaving the rice bed

$P_2 = P_1 - h1\rho' g$

$P_3 = P_4 + h_2\, \rho' g$

$P_4 = P1 - (h_1+h_2)\rho g$

$P_2 - P_3 = (h_1+h_2)(\rho-\rho')g$

$\Delta P = H\, \Delta\rho\, g$

$V = k\frac{\Delta P}{X}$, (k= is constant, 0.03)

$A = \frac{1}{X}\, m^2$

Q = VA m^3/min

$$Q = \frac{0.03\,\Delta P}{X} \times \frac{1}{X} = \frac{0.03\,H\,\Delta\rho\, g}{X^2}$$

$$X = \left(\frac{0.03\,H\,\Delta\rho\, g}{Q}\right)^{\frac{1}{2}}$$

$$\therefore\ X = \left(\frac{0.03\,H\,\Delta\rho\, g}{1.5}\right)^{\frac{1}{2}} \text{ to } \left(\frac{0.03\,H\,\Delta\rho\, g}{8}\right)^{\frac{1}{2}}$$

This range is the depth of the paddy bed for 1 m^3 of paddy. Using this data, depth of the paddy bed is assuming 100 mm for 0.83 m^3 of paddy.

iv Size of the solar collector

Received energy from the collector = $I \times t \times \eta_c$

$$\text{Collector area} = \frac{\text{required energy for the dryer}}{\text{received energy from the collector}}$$

v The Air Inlet Area and Air Velocity

The perforated floor should be placed at waist level, or about 80 cm from the ground. If the width of a paddy box suitable range is 100 cm, then the collector wide is 300 cm. The slope of the inclined clear cover is 10 degrees or over. In this design, clear cover inclines 10 degrees from the perforated floor.

The air inlet of height = 65 – (tan 10º × 300)

The air inlet area = the air inlet of height × 830cm

Table 1. Design parameter and assumptions

Drying capacity	0.5 ton/batch
Initial weight of the paddy, $G_{wet\ grain}$	500kg (0.5 ton)
Initial moisture content of the paddy, Mo	22 % (w.b)
Final moisture content of the paddy, Mf	14 % (w.b)
Drying period	2 days
Density of the paddy	600 kg/m^3
Type of collector	Flat plate solar collector
Specific latent heat of vaporization of water, L	2.5 MJ/kg
Collector efficiency, η_c	0.35
Solar insolation for May, I	MJ/day m^2

Table 2. Results of Solar Paddy Dryer for Various Drying Capacity with Same Chimney Heigh

Drying capacity (kg)	500	750	1000
Required energy (MJ)	116.28	174.42	232.5
Depth of the paddy bed(mm)	100	100	130
Size of the paddy box (m^2)	8.3	12.5	12.85
Collector area (m^2)	25.458	38.187	50.903
Air inlet area (m^2)	0.996	1.5	1.542

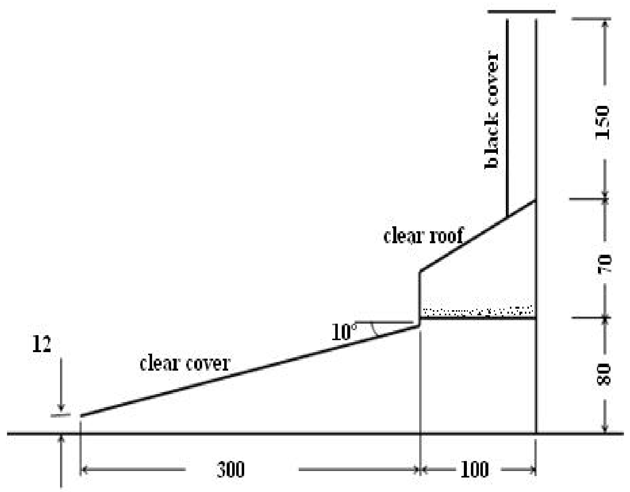

Figure .4. Dimension of the dryer

5) CONCLUSION

In this paper, the design of indirect solar paddy dryer with chimney is calculated. The solar paddy dryer is analyzed by changing the drying capacities with same chimney height. Due to increase in drying capacity, the amount of paddy volume is increased. But by keeping the width of paddy box constant, the length of paddy box and depth of paddy is changed for its increase in volume. Without changing the chimney height, the new collector area form more heat to dry up and outlet air become slow which can cause overheat to the paddy. The effect of overheated, due to the same chimney height, the paddy can be broken and the quality of rice can be poor. Hence to avoid overheat problem it should be suggested to change the outlet air move faster by increase of chimney height .This dryer design should be additionally considered for chimney cross section area. In this paper, the design calculation for 500 kg of solar paddy dryer, it can be seen that the required energy to remove moisture content from 22 % to 14 % for paddy is 116.28 MJ. The received energy from the collector is 6.525 MJ/day m^2 for May. The depth of the rice bed is 100 mm. So, the floor area of the paddy bed is 0.83 m^2. The required collector area is 25.458 m^2 and the size of the air inlet area is 0.96 m^2. In this design, solar chimney height is used 3m from the ground level.

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