# Design of Mixed Mode Solar Dryer

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**Abstract-- Mixed mode solar dryer composed of solar collector and a solar drying chamber. The flat plate collector is the most widely used solar collector for domestical and industrial purpose because it is simple and portable design and required less maintenance. The drying process uses only a solar energy. The air allowed in through air inlet is heated up in the solar collector channeled through the drying chamber where it is utilized in drying and (removing the moisture content from the agriculture product). This paper presents a design of mixed mode solar dryer for drying agriculture product which is fully based on geographical location in puducherry and metrological data were obtained from proper design specification.**

***Key words—solar collector; solar dryer; agriculture product;***

## I. INTRODUCTION

Solar energy is a very large, inexhaustible source of energy. The power from the sun intercepted by the earth is approximately $1.8\times10^{11}$MW which is many thousands of times larger than the present consumption rate on the earth of all commercial energy sources. Presently there are several applications which use the solar energy as a source such as water heater, space heating, and distillation, drying, cooking, power generation.

One of the traditional uses of solar energy has been for drying agriculture product. The drying process removes moisture and helps in the preservation of the product. Traditionally, drying is done on open ground. The disadvantages associated with this system are that the process is slow and that insect and dust get mixed with the product. The use of solar dryers helps to eliminate this factor. Drying can be done faster and a better quality product is obtained. In addition to this operating cost is reduced as compared to electrical dryer. With drying, most agriculture product can be preserved and this can be achieved more efficiently through the use of solar dryer.

Solar dryer are a very useful device for:

- Agricultural crop drying.
- Food processing industries for dehydration of fruits and vegetables.
- Fish and meat drying
- Dairy industries for production of milk powder.
- Seasoning of wood and timber.

Several type of solar drying system are available, they are cabinet solar dryer, indirect solar dryer and mixed mode solar dryer. In this paper mixed mode solar dryer is used. This dryer has an advantages of reducing the drying time of product which is due to the solar radiation falling on both solar collector and drying chamber. As a result there is an easy removal of moisture from the product. This is possible by passing preheated air from the solar collector and also direct drying will take place in the drying chamber.

## II. MATERIAL AND METHOD

*General description*

The most commonly seen design type of mixed mode solar dryer has solar collector which is coupled with drying chamber. Both are made up of wooden boxes with glass cover. There is an air inlet to the solar collector where air entering and is heated up by the solar radiation, the hot air rises through the drying chamber passing through the tray and around the food, removing the moisture content and exists through the air outlet near the top of glass cover.

The hot air acts as the drying medium; it extracts and conveys the moisture from the product to the atmosphere under forced convection, thus the system is active solar system and mechanical device (i.e. blower or fan) is required to control the intake of air into the dryer.

MATERIAL USED

The following materials were used for the construction of the mixed mode solar dryer:

- Wood (plywood) - as the casing of the entire system. In addition with glass wool is used to minimize the conduction and convection losses to the atmosphere.
- Glass (low iron tempered glass) – as the solar collector cover and the cover for drying chamber. It permits the solar radiation into the system.
- Aluminium plate of 1mm thickness with smoke black coating for absorption of solar radiation.
- Aluminium tray for placing drying material.

III. Design consideration

1. Temperature – the minimum temperature for drying product is 30°C and the maximum temperature is 70°C, therefore 50°C and above is considered average and normal for drying agriculture product.
2. The design was made for optimum temperature for the dryer. $T_o$ of 70°C and the air inlet temperature $T_i$ of 30°C (approximately outdoor temperature).
3. Air gap – a gap of 50mm should be created as air inlet and air passage.
4. Mass flow rate – assuming the maximum flow rate is 0.015Kg/s and minimum flow rate is 0.013Kg/s.
5. Dimension – assuming the width of solar collector is 640mm and absorber plate is 600mm. The average dimension of dryer was 400×330×300mm. the dryer was roofed with glass tilted at the same angle with that of solar collector. The air inlet of the collector is 120×40mm and the outlet is same as the inlet.
6. Dryer tray – aluminium was selected as dryer tray to aid air circulation within the drying chamber. The tray dimension is 350×280mm with wooden stick used as a frame.

Plywood is used to make a drying chamber and glass cover at the top of dryer for direct drying of product from the direct solar radiation.

IV. DESIGN CALCULATION

Peak radiation is obtained when the declination angle is maximum of 23°26' on June 21.

The values A, B and C are constant which is predicting solar radiation on clear days.

For June 21:

Beam radiation ($I_b$) and = 886W/$m^2$

Diffuse radiation ($I_d$) = 124W/$m^2$

Global radiation ($I_g$) = 1010W/m2

Latitude of puducherry ($\varphi$) = 11°55'

1. Angle of tilt($\beta$) of solar collector

   It states that the angle of tilt of the solar collector should be

   $\beta = 10° + \text{latitude } (\varphi)$

   Hence the value of $\beta$ used for the collector

   $\beta = 10° + 11°55' = 21°55'$

2. Declination angle($\delta$)

   $\delta = 23.45\sin [(360/365)\times(284+n)]$

   n - Number of days = 172

   $\delta = 23° 26'$

3. Angle of incident($\theta_z$)

   It states that the angle of incident of solar radiation on horizontal surface should be

   $\cos \theta_z = \sin\varphi \sin\delta + \cos\varphi \cos\delta \cos\omega$

   At 12 noon $\omega = 0$

   $\cos \theta_z = 0.98$

   The angle of incident of solar radiation on tilted surface should be

   $\cos\theta = \sin(\varphi-\beta) \sin\delta + \cos(\varphi-\beta) \cos\delta \cos\omega$

   $\cos\theta = 0.835$

4. Incident solar flux absorbed in the absorber plate(S)
   A research obtained the value of absorbed solar flux for puducherre on tilted surface as
   S = 678W/$m^2$
5. Determination of collector area and dimension.
   The maximum mass flow rate of air = 0.015Kg/s

The width of solar collector (B) assumed to be 640mm and absorber to be 600mm.

Heat gain $Q = m \times Cp \times \Delta T$
Therefore $Q = S \times Ap$
$Ap = (m \times Cp \times \Delta T) / S$
$Ap = (0.015 \times 1005 \times 40) / 678 = 0.889 m^2$
The length of absorber (La) was taken as;
La = Aa / Ba = 0.889 / 0.6 = 1.4816m Thus, the length of the absorber was taken approximately as 1.5m.
Therefore, absorber plate area was taken as $(0.6 \times 1.5) = 0.90 m^2$
Length of solar collector was taken as (1.5+0.04) = 1.54m

6. Determination of heat losses from the solar collector
Total energy transmitted and absorbed is given by
$Q = (S \times Ap) - Q_L$
$m \times Cp \times \Delta T = (S \times Ap) - (U_L \times Ap \times \Delta T)$
$U_L = ((0.9 \times 678) - (0.013 \times 0.90 \times 40)) / 0.9 \times 40$
$U_L = 2.433 W/m^2\text{-}K$
Therefore,
$Q_L = 2.433 \times 0.9 \times 40$
$Q_L = 87.59W$

## V. CONCLUSION

From the above design, it has been concluded that solar radiation can be effectively and efficiently utilized by the mixed mode solar dryer for drying the agriculture products. From the result which has been obtained, the area of the collector is small as portable. Hence the whole setup can be carried anywhere easily. By the use of this design data construction of flat plate collector is to be done in order to validate the calculated result.

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