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Design of Air Preheater for Solar Dryer for Drying Cereals

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Abstract

This paper explains about various factors which are to be considering while designing solar dryer for agriculture products. It includes the major parts like air pre heater, air duct, and cabin for keeping agricultural products. Out of these parts of air pre heater is important as solar energy is available in attuned form & we have to concentrate it with help of solar collectors. In collectors absorber plates are made up of good thermal conductor like copper, aluminium so the plate is get heated due to solar radiation & hence air is heated by the convection process by forcing the air to flow over absorber plate & this heated air is directed towards the cabin through ducts. After that heated air is made to flow over agricultural products specially cereals lying in the cabin which is a closed space having number of trays placed in vertical shell with suitable distance & heated air takes away moisture present in it.

Introduction

There is one strong bond between humans & solar energy, in our Indian culture sun represents basic source of energy and that is why people pray to the sun. Humans are using solar energy since from ancient times; one of the traditional uses of solar energy is to dry agricultural products. Basically drying requires as most of crops & food are grown & harvested in particular period of year so we have to preserve it so that we can consume it throughout the year. On of the best method to preserve food is to store it at specific temperature & humidity which is easily & inexpensively obtained by solar energy known. Drying with help of solar energy is known as sun drying but involves many disadvantages like contamination of the products by dust, birds, animals and insects, spoiling due to rain, wind and moisture, and the method totally depends on good weather conditions. Further, the process is labour intensive, unhygienic, unreliable, time consuming, non-uniform drying, and requires a large area for spreading the produce out to dry. There are many other modern methods are available for preservation like heating with mechanical or electrical heaters or even store at subzero temperatures but it requires electricity or other form of fuel which used as energy As we know there is tremendous rise in costs of fossil fuels & uncertainty of availability world is leading towards the use of solar energy in our day to day life. In case of developing nations like INDIA the adoption of non conventional energy sources has become compulsion. As Indian economy is based on agricultural produce per year so that we have to focus on reducing cost of processing of agricultural outputs so that overall profit will increase & available to consumer at cheaper rate. 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 Dryer

Solar dryer is closed space which is used to dry products in better & hygienic way. Solar dryers have more advantages over sun drying if it is correctly designed. They give faster drying rates by heating the air to 10-30 ^{0}C above surroundings, which causes the air to move faster through the dryer, lowers its humidity also deters insects. The faster drying results into reduced risk of spoilage, improves quality of the product and gives a higher output, so reducing the drying area that is required. Solar dryers also protect foods form dust, insects, birds & animals. They can be constructed from locally available materials at a relatively low capital cost & 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. Solar food drying can be used in most areas but how quickly the food dries is affected by many variables, especially the amount of sunlight and relative humidity. Typical drying times in solar dryers range from 1 to 3 days depending on sun, air movement, humidity and the type of food to be dried.

MATERIALS USED TO CONSTRUCT SOLAR DRYER

In any design procedure selection of material is having considerable wattage as all the standard values we are referring from design data book are depends upon what material we have selected. While selecting material one should consider its mechanical, physical & chemical properties so BIS recommended following materials

Table 1. Materials for various parts of air pre heater

Sr.No.	Part	Material Used
1	Absorber Plate	Copper or Aluminium
2	Transparent cover	Toughened glass
3	Insulation	Glass Wool or Rock Wool
4	Casing	Aluminium with epoxy coating externally

Flat-Plate Solar Collector

A grain-drying solar-assisted system is composed of a solar collector, a fan, an additional energy source for air heating, a plenum (for air distribution) and a bin batch drying system. Flat-plate collectors are used in air and water heating systems. The incident solar energy is partially absorbed by a dark and opaque surface, part of this energy is transferred to the fluid and the remainder is lost to the environment. The collector plate is covered with a glass in order to minimize convective losses and create a “green house” effect. Figure 1 shows the outline of a flat-plate collector for air heating and the main parameters involved in heat transfers: incident solar radiation (I), cover heat loss coefficient (U_c), coefficient of convective heat transfer between cover and air (h_{c-a}), coefficient of convective heat transfer between plate and air (h_{p-a}) coefficient of radiation heat transfer between plate and cover (h_{rp-c}), bottom heat loss coefficient (U_{bottom}), ambient temperature (T_{amb}), cover temperature (T_c), air temperature (T_a) and mean plate temperature (T_{pm}).

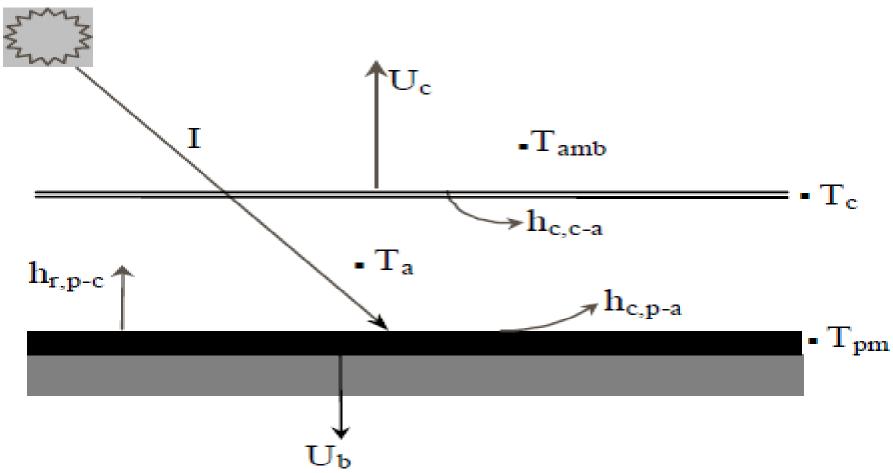

Figure 1: Flat-Plate Solar Collector Heat Transfer Parameters.

According to Plate Efficiency Factor [4] presented an expression (equation (1)) to describe the performance of a solar collector by an energy balance involving energy gain and thermal and optic losses. Since this equation assumes the mean plate temperature to be equal to the collector inlet air temperature (T_i), a heat removal factor (F_R) is introduced:

$$q = A_{plate}F_R\,[I(\zeta\alpha) - U_L(T_{in}-T_{amb})]\ldots\ldots\ldots(1)$$

(U_L is the collector heat loss coefficient)

The instantaneous efficiency of the flat-plate solar collector (η) is defined as the ratio of the rate of useful energy supplied by the collector (q) to the rate of incident solar energy in its Plate area A_{plate}:

$$\eta = q/IA = F_R\,(\zeta\alpha) - F_R\,U_L\,[(T_{in}-T_{amb})/I]\ldots\ldots..(2)$$

(τα is the absorptance-transmittance product).

The products $F_R(\tau\alpha)$ and F_RU_L are assumed to be constant terms. They can be experimentally determined by plotting η versus $(T_i-T_{amb})/I$ as a independent variable and applying a linear regression to the set of experimental points. Two characteristic parameters of solar collectors are obtained: one is related to thermal losses and gains (F_R (τα)) and the other is related to thermal losses (F_RU_L). The ASHRAE 93-77 standard gives the procedures to characterize a flat-plate collector and to calculate its characteristic parameters.

Energy Storage Collectors

The main characteristic of energy storage collectors is the high thermal inertia, represented by a high value for the collector time constant [5]. The advantage of this unit in the drying process is the capacity to avoid temperature peaks during the day and to continue transferring heat even when the incidence of solar radiation ends. However, due to their nature, characterization of these collectors based on ASHRAE 93-77 standard Equation (2) does not supply appropriate information about operation of this equipment. An alternative is to consider the storage collector as a flat plate and to use the daily efficiency η (ratio of the heat supplied by the solar collector to the total incident radiation in a whole

$$ń = \int q\, dt / (A_{plate} \int I\, dt)\ldots\ldots\ldots(3)$$

despite their high thermal inertia, concrete collectors have linear behaviour similar to that in the instantaneous efficiency model [6] :

$$ń = a – b\, [(T_{in}-T_{amb}) / H_T]\ldots\ldots\ldots (4)$$

Where T_{in} is the mean inlet air temperature, T_{amb} is the mean ambient temperature, H_T is the daily incident radiation on a tilted surface and a and b are the daily characteristic parameters.

Empirical Correlations

Absorber plate present in the solar heater assembly is get heated due to solar radiation falling on it. An air from environment will enter into the solar heater assembly where the absorber plate is placed. As the air present over there is get heated due to convection . this heated air will move forward as its density will drop and it enters into garbage box where the moist garbage is placed. This type of circulation of heated air is called thermo siphon action. While heated air flowing through the garbage will remove the moisture from it. Provision of electrical heating coil will come into picture when drying is required to carry during nights & cloudy days.

Klein et al. determined a correlation between the solar fraction f (ratio of the heat supplied by a solar system Q_s to the energy demand of the process Q_p) and two dimensionless design parameters (X and Y) for an air heating solar system [7]:

$$F = Q_s / Q_p \ldots\ldots(5)$$
$$X = A_{plate}F_R\, [U_L(100 - T_{amb})] / Q\ldots\ldots(6)$$
$$Y = A_{plate}F_R\, [(\zeta\alpha)_m H_T] /Q\ldots\ldots\ldots(7)$$
$$f\ 1.040Y – 0.064\, X – 0.159Y^2 + 0.00187X^2 – 0.0095Y^3 \ldots\ldots(8)$$

The above correlation assumes a system with an air flow rate between 5 and 21 m^3/s, a slope equal to the local latitude plus or minus 15° and thermal storage pebble diameters between 1 and 3 cm. The correlation of (Equations 9 and 10) uses only one design parameter (Y) because when $T_i=T_{amb}$ the heat losses term in Equation (1) becomes negligible.

$$f = Y;\ 0 < Y < 0.2\ldots\ldots\ldots(9)$$
$$f = -0.009 + 2.0251Y – 3.0482$$
$$Y^2 = 1.5263Y^3;\ 0.25 < Y < 0.554 \ldots\ldots\ldots(10)$$

Conclusions

By following above generalized design procedure one can determine the Area of plate by considering overall radiation falls on it & various losses from the pre heater i.e. through conduction & radiation.

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