TECHNICAL NOTE

EXPERIMENTAL SIMULATION OF A GRAIN DRYING SYSTEM

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(Received 9 February 1993; received for publication 20 December 1993)

Abstract—In this Technical Note, an experimental simulation of a grain drying system has been tested. The experimental observations have been used to evaluate the drying time for wheat crop for a given moisture content. The effect of storage has also been included in the present design. It is observed that the fluctuation in temperature is significantly reduced due to the storage effect.

Solar crop dryer Solar energy Drying processes Food processing

INTRODUCTION

Solar dryers should be considered to replace sun drying when a higher quality product is desired, especially when climatic conditions render sun drying difficult or impossible to achieve without severe losses to quality and quantity.

The process that occurs during drying of grains includes the movement of water through the interior of the grain and the loss of water vapour from the grain surface. The occurrence of the latter process depends on the difference between the vapour pressure of the drying air and the vapour pressure of the water in the grain. The latter depends on the moisture content and the grain temperature. When these vapour pressures are equal, the moisture content within the grain remains constant at a value called the equilibrium moisture content (EMC).

If the two vapour pressures are not equal, the grain will lose or gain moisture depending, respectively, on whether the actual moisture content is greater or less, than the equilibrium moisture content (EMC).

The drying requirements of agricultural and food products vary from product to product. The moisture to be removed from a particular product is determined by the initial moisture content of the product and the safe storage moisture content of the dried products. For heated air drying operations, where the drying temperature and relative humidity can be controlled, each product has its specified drying conditions for best quality. In drying using solar energy, efforts should be made to obtain these drying conditions as far as possible. In solar drying, the products have yet another requirement as to whether or not they can be exposed to direct sunlight.

If the temperature of the drying air is raised by only a few degrees, the relative humidity of even humid air is lowered enough to make it effective for crop drying [1–14]. The 10–15°F rise in the temperature of the air is enough to reduce the relative humidity of the air to about 60% or less, which is quite useful for drying cereal grains. Most cereal grains at the time of harvesting contain moisture contents of between 20 and 30% wet weight. The safe storage moisture content is of the order of 9–11% wet weight.

In this communication, the effects of the thermal storage and the crop have also been taken into account. Numerical computations have been carried out for a steady state condition.

ENERGY STORAGE

Solar energy is a time-dependent energy source, and the energy needs for a very wide variety of applications are also time dependent, but in a different fashion than the solar energy supply.
Consequently, the storage of energy or other product of the solar process is necessary if solar energy
is to meet substantial portions of these energy needs.

The optimum capacity of an energy storage system depends on the expected time dependence
of solar radiation availability, the nature of the loads to be expected on the process, the degree
of reliability needed for the process, the manner in which auxiliary energy is supplied and an
economic analysis that determines how much of the annual loads should be carried by solar and
how much by the auxiliary energy source.

Energy storage may be in the form of sensible heat of a solid or liquid medium, as heat of fusion
in chemical systems, or as chemical energy of products in a reversible chemical reaction. Mechanical
energy can be converted to potential energy and stored in elevated fluids. The products of solar
processes other than energy may be stored (e.g. distilled water from a solar still may be stored in
tanks until needed).

The choice of storage media depends upon the nature of the process. For water heating, energy
storage as sensible heat of the stored water is logical. If air heating collectors are used, storage in
sensible or latent heat effects in a particular storage unit is indicated, such as sensible heat in a
pebble bed heat exchanger. In passive heating, storage is provided as sensible heat in the building
elements.

The major characteristics of a thermal energy storage system are (a) its capacity, per unit volume
or weight; (b) the temperature range over which it operates, that is, the temperature at which heat
is added to an removed from the system; (c) the means of addition or removal of heat and the
temperature differences associated therewith; (d) the temperature stratification in the storage unit;
(e) the power requirement for addition or removal of heat; (f) the containers, tanks, or other
structural elements associated with the storage system; (g) the means of controlling thermal losses
from the storage system and (h) its cost.

A packed bed (pebble bed or rock pile) storage unit uses the heat capacity of a bed of
loosely-packed particulate material to store energy. A fluid, usually air, is circulated through
the bed to add or remove energy. A variety of solids may be used, rock being the most widely used
material. A well designed packed bed using rocks has several characteristics that are desirable
for solar energy applications; the heat transfer coefficient between the air and the solid is high,
which promotes thermal stratification; the costs of storage material and container are low; the
conductivity of the bed is low when there is no air flow; and the pressure drop through the bed
is low.

A packed bed in a solar heating system does not operate with constant inlet temperature. During
the day, the variable solar radiation, ambient temperature, collector inlet temperature, load
requirements, and other time-dependent conditions result in a variable collector outlet temperature.
For a variable collector outlet temperature, the use of thermal storage gives reduced temperature
fluctuations [15]. To reduce thermal fluctuations, thermal storage has been used, and the simulation
has been carried out.

EXPERIMENTAL SIMULATION

The experiment was set up and simulated in the laboratory. The hot air was provided through
the heat convector. The heated air was passed through the drying chamber, and the temperature
of the inlet air \( T_i \) varied between 50 and 70° approximately. The heated air passed through the
thermal storage number 1 (temperature \( T_1 \)). After that, the air passed through the drying material
in chamber 2 (temperature \( T_2 \)). Then, the heated air is passed through the thermal storage number
2 (temperature \( T_4 \)), and then through the drying material in chamber 3 (temperature \( T_3 \)). The outlet
air temperature is \( T_4 \). The various temperatures were measured with the help of thermocouples and
mercury thermometers.

Heat convector

A USHA SHRIRAM FH-812T heat convector was used for heating the air. It is a single phase
50 Hz, 230 V a.c. device with two heating coils of power rating of 1000 W each. The fan is of
2300 rpm and 21 W. The heat convector has a thermostat value to keep the convector outlet
temperature uniform.
**Drying material**

In chamber number 2, wheat grains were kept for drying. The safe storage moisture content for wheat grains on the wet weight basis is 11%. In chamber number 3, the wheat crop was taken to find its temperature change with time. The 0.5 kg of drying materials were taken in each of the drying chambers.

**Heat storage material**

Rocks have been used for sensible heat storage. The average size of the rocks was 5–8 cm in diameter. The density of rocks was 1750 kg/m³ and their specific heat was 0.81 kJ/kg-K.

**Drying equation**

The equation governing the drying of grains is

\[ 1 - RH = \exp(-cT_pE^n) \]

where

- \( \bar{T}_p \): Average temperature of the drying material
- RH: Relative humidity
- \( E \): Equilibrium moisture content
- \( c \) and \( n \): are constants.

For wheat

\[ c = 10.6 \times 10^{-7}, \]

\[ n = 3.03. \]

Using the above equation, calculations have been made for the change in moisture content with time. The results are given in Fig. 5.
CONCLUSIONS

On the basis of experimental simulation, the following conclusions have been drawn:

(1) The steady state condition for drying the wheat crop with and without thermal storage is reached after about 2 h for a given storage capacity and 1 kg of wheat grain (drying material). Figs 1 and 2.
Fig. 4. Fall in moisture content with time.

Drying rate, \( R = \frac{\text{Amount of moisture removed}}{(\text{Time}/100) \times (\text{weight of sample in g})} \)

Fig. 5. Fall in drying rate with time.
(2) The moisture content of the drying material decreases with increase in time for a given temperature, as expected, Fig. 4.

(3) The drying rate is reduced with the decrease of moisture content.

(4) The steady state condition will take a larger time to achieve for high thermal capacity of the rock bed thermal storage, Fig. 3.

(5) By using thermal storage, the maximum temperature of the drying material is reduced within a safe range, thereby improving the quality of the agricultural procedure.

REFERENCES


