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The Study of Grains Drying in Tapered Fluidized Bed

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Abstract: ***Drying is essentially a process of simultaneous heat and mass transfer. In most drying operations, Water is the liquid evaporated, and air is the drying medium. Heat, necessary for evaporation, is supplied to the particles of the material and moisture vapor, evaporated liquid, is removed from the material into the drying medium. The objective of this paper is to describe the development of tapered fluidized –bed wheat drying including the mathematical model used. Important experimental results from both laboratory-scale and commercial dryers will be presented.***

Keywords: Fluidized bed, drying, and mathematical model

1. Introduction

Fluidization tapered vessels has been used in various areas of the process industry A relatively small apex angle has been selected to accommodate the increase in gas volume with height in a deep bed [1]. A large apex angle has been selected to suppress slugging and to reduce bed expansion and its fluctuation effectively over a much wider range of fluidization velocities [2, 3]. Moreover, a tapered vessel sandwiched by fore and aft cylindrical sections has been proposed as a modification of this kind of tapered vessel [4, 5].

Most of the gas–solid fluidization behavior studies that have been reported are for straight cylindrical or columnar fluidized beds, although a considerable proportion of the fluidized beds have inclined walls or have a tapered bottom section. A velocity gradient exists in the axial direction, leading to unique hydrodynamic characteristics. Due to this characteristic, tapered fluidized beds have found wide applicability in many industrial processes such as, waste water treatment , immobilized bio film reaction, incineration of waste materials, coating nuclear fuel particles, crystallization, coal gasification and liquefaction and roasting sulfide ores , food processing , etc.

In many practical applications, drying is a process that requires high energy input because of the latent heat of water evaporation and relatively low energy efficiency of industrial dryers. That is, expensive energy is depleted only to produce low grade heat for drying. Fluidized beds are currently used commercially for drying such materials as granular materials, cereals, polymers, chemicals, pharmaceuticals, fertilizers, crystalline products and minerals.

Drying is essentially a process of simultaneous heat and mass transfer. In most drying operations, Water is the liquid evaporated, and air is the drying medium. Heat, necessary for evaporation, is supplied to the particles of the material and moisture vapor, evaporated liquid, is removed from the material into the drying medium. Fluidized drying of granular products of solids can be either batch wise or continuous. Batch operation is preferred for small scale production and for heat sensitive materials. Fluidized bed dryers are widely used in a number of industry sectors to dry finely divided 50–5000lm particulate materials. Compared with other drying techniques, fluidized bed drying offers many advantages. High heat and mass transfer rates between the gas and the particles are possible because of good contact or large contact area between the particles and gas, good and rapid mixing of solids, nearly uniform moisture content distribution throughout the bed, closely controllable temperature in the bed, ease in transport and handling of particles, and simplicity in construction. On the other hand, the disadvantages include high pressure drop, attrition of the solids and erosion of the containing surfaces.

2. Experimental Set Up

The gas distributor was 2mm thick with 2mm perforations. A fine wire mesh of 0.2mm openings was spot welded ever the distributor plate to arrest the flow of solids from the fluidized bed into the air chamber. Air from the blower was heated and fed into the air chamber and into the fluidization column. The electrical heater consisted of multiple heating elements of 2 KW rating. The timer is provided in which time can be maintained from 0- 80 min.

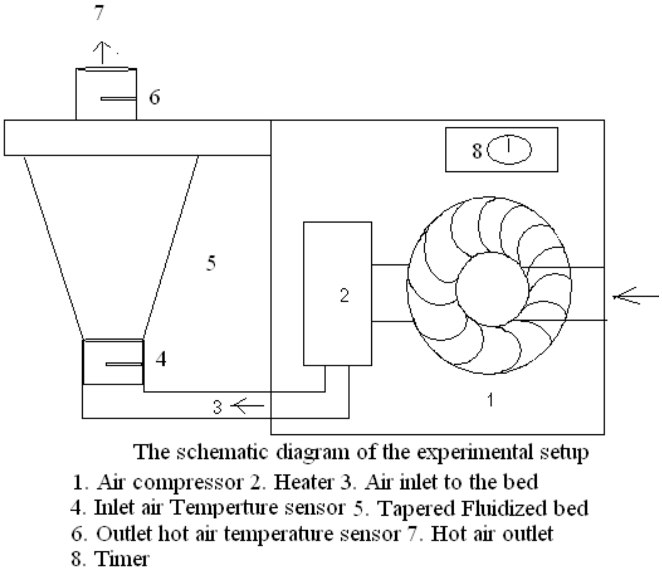

Figure 1: Systematic Diagram of Fluidized Bed Dryer

3. Method

3.1 Test Material

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3.2 Procedure for Drying

A known weight of the material is taken into the fluidized bed dryer column. The time, temperature and flow rate are set. The power is switched on. The dried material is taken out after the process is over and is weighed. The temperature, time, gas velocities are changed and weights of dried material is noted for three different temperatures, three different drying times, two gas velocities, two sizes of drying material and the results are studied.

4. Results and Discussion

The efficiency of the dryer can be calculated using the equation (1)

$$\eta e = \frac{Wd\,[\,hfg\,(\,\Delta Mp) + cm\,(\,Tm2 - Tm1\,)]}{m.da\,(\,h1 - h0\,)\,\Delta t} \quad \text{------------ (1)}$$

The specific heat of the wheat grain [3] is given by the equation (2)

$$cm = 1398.3 + 4090.2[Mp/(1 + Mp)] \quad \text{----------------(2)}$$

Where Mp is moisture content of grain.

The moisture content, Mp is given by

$$Mp = (Wb - Wd) / Wd \quad \text{----------------------(3)}$$

In this study, the drying characteristics of wheat in a fluidized bed were experimentally observed with three different temperatures, three different times of drying, different initial moisture contents and two different gas velocities. The specific heat for the material and efficiency of dryer were calculated for each moisture content, drying time and temperature.

Effects of temperature, time and initial moisture content on drying are shown in Graphs 1, 2. The effect of temperature and time of drying on dryer performance is shown in Graph 3. The effect of gas velocity on efficiency of drying of wheat is shown in Graph 4. The moisture removed vs. gas velocity is shown in Graph 5.The effect of particle size on drying rate for mustard seeds is shown in Graph 6.

The inferences are

1. Effect of Temperature on drying
As the temperature increases, the drying of the grains also increases. Increasing drying air temperature will increase efficiency on the drying process but there is a practical limitation due to damage of the material caused by the extent of stress cracking. For wheat, the drying temperature should not be more than 65 °C.

2. Effect of drying time
As the drying time increases, the amount of water evaporated increased.

3. Effect of Initial moisture content
The efficiency is slightly higher for the grain material with higher initial moisture content.

4. Effect of gas velocity on efficiency
The increase of gas velocity from 1.95 m/s to 3.8 m/s, shows that it would be advantageous to use air velocity as low as possible.

5. Effect of Particle Size
An increase in particle size decreases the drying rate. This reduction is due to reduction in surface area per unit weight of solids.

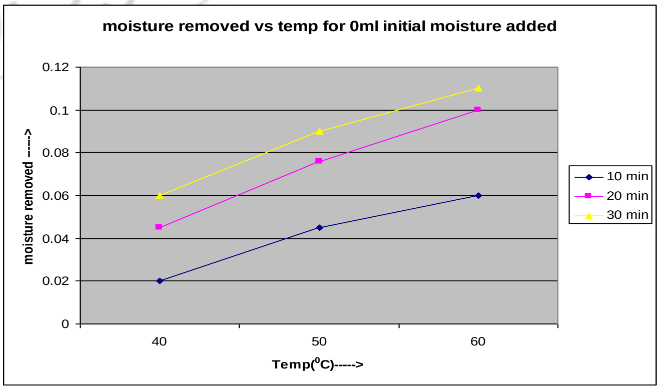

Figure 2: Plot of Temperature and Moisture Removed 0ml water added.

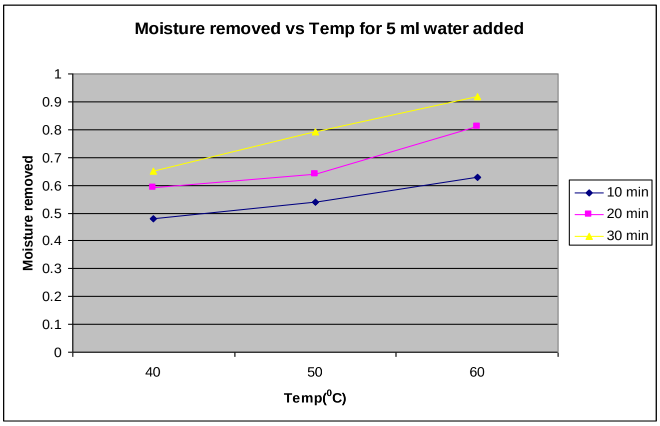

Figure 3: Plot of Temperature and Moisture Removed 5 ml water added.

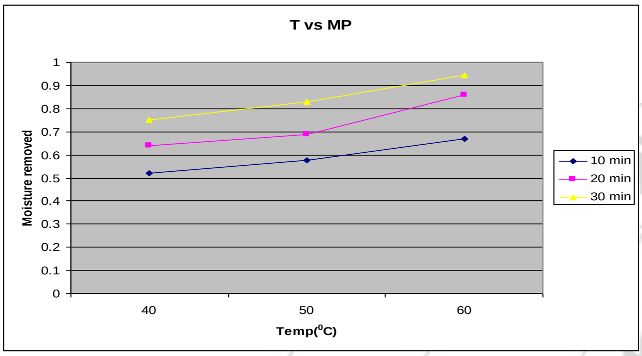

Figure 4: Plot of Temperature and Moisture Removed 10 ml water added

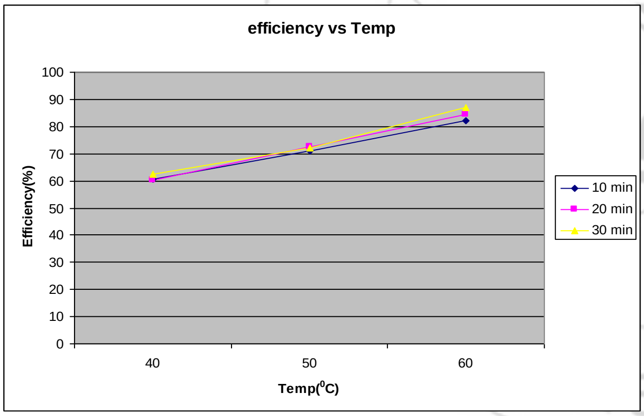

Figure 5: Plot of Temperature and Drying Efficiency

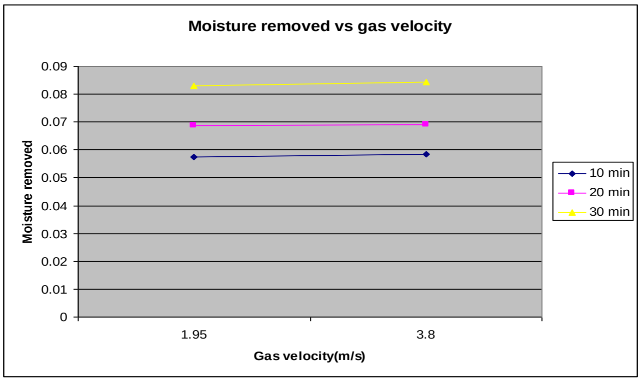

Figure 6: Moisture Removed and Gas Velocity.

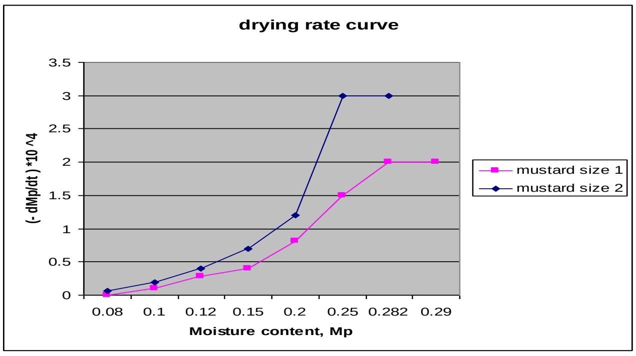

Figure 7: Moisture Content and Drying Rate.

5. Conclusions

In this study, the drying characteristics of wheat in a fluidized bed were experimentally observed with three different temperatures, three different times of drying, different initial moisture contents and two different gas velocities. Temperature has a more important effect on the drying when compared with that of the mass flow rate. That is, the mass flow rate of air has not played an important role on drying performance as much as the temperature, since moisture extraction rate is only slightly enhanced by an increase in air mass flow rate when compared with an increase in temperature. Thus, in order to increase the drying performance, the higher air temperatures should be preferred rather than higher air mass flow rates. However, further work is required for developing the model equations for drying and determining the optimal conditions of drying.

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