ANALYSIS OF RECTANGULAR FLUIDIZED BED DRYER WITH TRIANGULAR WAVY WALLS

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ABSTRACT

This review intends to study heat transfer in fluidized bed dryer by the use of rectangular type chamber with triangular wavy walls and without triangular wavy walls. Modifications in triangular wavy walls can be done to produce stronger turbulence flow inside. This will lead stronger turbulence and longer residence time inside chamber. Fluidization is the phenomenon in which solid particles in a gas or a liquid type are suspended and it has many applications in many physical, chemical industries. Fluidized bed dryers have many usages in chemical, agricultural and medical industries.

Keywords: Drying Chamber, Drying Time Rate, Heat Transfer, Rectangular Type Fluidized Bed, Wavy Surface.

I INTRODUCTION

Drying is the process of heat and mass transfer. Heat is necessary for evaporation which is supplied to the particles of the material and moisture vapor is removed from the materials into the drying medium. Heat is transferred by convection from the surrounding to the particles surface and from there, by conduction, further into particle of material. Moisture is transported in the opposite direction as a liquid or vapor; on the surface it evaporates and passes on by convection to surrounding. The transfer of heat depends on many factors, such as air temperature, initial moisture content, desired final moisture content, relative humidity, air flow rate, exposed area of material, pressure and heat transfer convection coefficient. Basically, high temperature air with very low relative humidity is preferable for fast drying process. Fluidized bed dryers (FBD) are used extensively for the drying of wet particulate and granular materials that can be fluidized. The Major reasons to use such dryers in those industries are:

1) Height heat and mass transfer coefficients due to gas-solid contact;
2) High quality products produced because of solid-gas / air proper mixture;
3) They are suitable for operations in great scale;
4) They have low service and maintenance cost;
5) Gas flow voids particles crack and fraction.

High application of such dryers has led to many researches in this field which mostly are depended an experimental equations and today many experimental equations are available to predict heat and mass transfer coefficients provided from these researches. The significant point is that in all of these researches, every equation has been presented in specific condition limit of fluidization regime type so conditions dominated on problem have significant importance to use these equations because every equation has validity on specific domain of particles type, fluidization regime, specific pressure and temperature.

1.1 Rectangular chamber with 45^0 wavy walls

The experiment on fluidized bed drying technique was conducted by Thianpong et al. [1]. That technique gave high efficiency in removing moisture from the content but the technique has limitation of itself which made that efficiency hard to improve. As per their analysis unsymmetrical flow was another way for drying and then the objective of that work investigated the drying kinetics and drying rate of peppercorns on unsymmetrical flow under the effect of rectangular fluidized-bed with wavy surfaces technique. Thus, the rectangular fluidized-bed (RFB) with 45^0 wavy surfaces technique was preferable. The typical RFB technique provided lower oscillation. That caused low heat transfer rate between peppercorns and hot air leading to lower mass transfer of moisture in the peppercorns for the typical RFB case.

1.2 Rectangular chamber with three backlog ratio of wavy walls

Promvonge et al. [2] analyzed the application of swirl flows created by wire-coil/twisted tape inserted and ribs mounted repeatedly in the chamber. They used passive heat/mass transfer enhancement technique in single-phase and two-phase internal flows since periodically positioned ribs/coils in the chamber interrupted hydrodynamic and thermal boundary layers, apart from inducing recirculation or secondary flows. Downstream of each rib/coil the flow separated, recirculated, and impinged on the duct wall and those effects were the vital reasons for heat/mass transfer enhancement due to fast mixing of the fluid particles in such chambers. The use of ribs/coils increased the heat transfer rate as well as raised considerable pressure loss. They have investigated work experimentally in the RFB and RFBW with three backlog ratios with the help of inserted ribs/coils in chamber. They have showed that the use of different air velocities leads to the significant effect on the drying rate for both the beds apart from air temperature. The RFBW with three backlog ratio gave higher turbulence intensity to reduced considerable the drying time. Thus, the RFBW with e/H=0.4375 was preferable in this study. Basically, high temperature air with low relative humidity was preferable for quick drying process. However, the maximum temperature of hot air was limited by the quality and application of the product. The highest temperature of hot air was chosen in each application because the higher air temperature, the quicker in drying and the lower in operation cost.. However, it provided substantial influence for the RFB with wavy surface technique. The trend of moisture reduction was different for both drying techniques. The rectangular fluidized bed with wavy surfaces technique which gave higher turbulence intensity to reduced drying time with increasing air velocity.

1.3 Circular chamber

Meziane [3] investigated modeling of the drying kinetics of agricultural products and vegetables in circular type chamber. Olive pomace, strawberries, potato slices, coconut, cocoa have been investigated in this experimentation. Several mathematical models have proposed to describe the drying behavior of agricultural products. Olive pomace contains significant oil content and important moisture content, depending on the olive oil extraction process. The olive pomace dried before its use as an animal feed, combustible or for solvent extraction of olive pomace oil. It has found for oil extraction, for instance, that the wet waste product fairly dried to give satisfactory yields (moisture content ranging between 5% and 10%). In addition, a greater yield and a higher grade of olive pomace oil could be obtained from pomace dried immediately after the extraction process of olive oil. It was necessary to dry agricultural waste quickly before spoilage activated. In this experimentation, the drying behavior of olive pomace in a fluidized bed dryer was studied at drying air temperatures ranging from 50^0C to 80^0C and fixed bed heights of 41, 52 and 63 mm. Highest value of R_2 and the lowest values of $\chi 2$ and RMSE were observed for 63 mm bed height and drying air temperature of 50^0C.

II ENERGY AND EXERGY ANALYSIS

Nazghelichi et al. [4] experimented that effect of drying condition on energy and exergy analysis of fluidized bed drying of moist materials such as fruits and vegetables. The primary objective of this study was to present energy and exergy analyses of fluidized bed drying of carrot cubes at different drying air temperatures (T), initial BD(bed depths), and CS (cube sizes). The effects of particles size, BD and drying air temperature on energy utilization, energy utilization ratio, exergy loss and exergy efficiency for fluidized bed drying of carrot cube were investigated in this paper. They also investigated the energy utilization and energy utilization ratio increased with increase in drying air temperature and BD while decreased with increase in cubes size. Exergy loss increased with increase in drying air temperature and BD while decreased with increase in the CS. Exergy efficiency increased with increase in drying air temperature and cubes size while decreased with increase in BD.

Experimentation on baker's yeast was conducted by Turkar et al. [5]. They have developed the drying model, based on material and energy balances around production scale fluidized bed for the drying of granular baker's yeast. The model accounted for product entrained through cyclone and energy loss through the body of the dryer, to improve the predictions of the model on production scale. The amount of product entrained from cyclones did not change much the predictive capacity of the model. In addition, the energy loss through the body of dryer was insignificant and the assumption of adiabatic conditions was justified. The model was applied to batch drying of granular baker's yeast with different granular dimensions.

III DRYING METHODS

The drying methods can be divided into two groups fixed bed drying methods and moving bed drying method. Akbari et al. [6] showed that effect of drying condition on baker's yeast. In this work, optimum operating parameters of an industrial continuous fluidized bed dryer for the production of instant active dry yeast were investigated. The dryer contained four zones separated with moving weirs. The operating conditions such as temperature, loading rate of compressed yeast granules, and hot air humidity had direct effects on both yeast activity and viability. The most important factors that affected the quality of the product were loading rate and the operational temperature in each zone on the bed. They have concluded that by optimization of drying conditions, it was possible to reach a high activity of the dried baker's yeast up to 660 ± 10 cm^3 CO_2/h, as well as high yeast cell viability up to 76%, which were 12% and 27% higher than the respective activity and viability of the yeast in normal operating conditions of the plant. If the temperature of the dryer is selected in a suitable range, the most important parameter affecting the quality of the baker's yeast is the loading rate of the dryer.

Arumuganathan et al. [7] showed that drying kinetics of milky mushroom slices (10mm) in a fluidized bed dryer was studied at air temperatures of 50^0C, 55^0C and 60^0C. Drying of milky mushroom slices occurred in falling rate period. In order to select a suitable drying curve, eight thin layer-drying models were fitted to the experimental moisture ratio data. The effective moisture diffusivity (D_{eff}) of mushroom increased as the drying air temperature increased. The moisture diffusivity in milky mushroom was found to increase from 1.55 to 4.02 x 10^{-9} m^2 s^{-1} during the initial stage of drying, and from 8.76 to 16.5 x $10^{-9}m^2s^{-1}$ during the later stage of drying. Drying at temperature of 60^0C required minimum activation energy to detach and move the water during the drying process.

Heat transfer in a fluidized bed dryer by the use of 3-phases model making done by Khorshidi et al. [8]. Some of these modifications have done on bed porosity in interstitial gas and involving changes of diameter and velocity of bubbles at bed height. Three-phase model making equations are linear differential ones which have been solved by finite difference method.

IV CONCLUSIONS

Rectangular type fluidization chamber with wavy walls can provide high turbulence and more residence time for fluidization of material. It requires less time for drying process. Energy consumption is low than other type of chamber. Drying process operates in between temperature of 50^0c to 100^0c and velocity in range of 1 m/s to 1.3 m/s. The rectangular fluidized bed (RFB) with 45^0 wavy surfaces technique has low performance than RFBW with three backlog ratio. Better performance can be achieved through different angles of triangular wavy walls and by using this technique in large scale, more drying rate can be achieved. However, further research work may be undertaken for different combination of triangular wavy walls.

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