International Journal of Application or Innovation in Engineering & Management (IJAIEM)
Web Site: www.ijaiem.org Email: editor@ijaiem.org
Volume 6, Issue 1, January 2017 ISSN 2319 - 4847

MATHEMATICAL MODELLING AND SIMULATION OF FLUIDIZED BED DRYING SYSTEM

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ABSTRACT

of all the unit operations used by the process industries, drying is probably the oldest and the most common one found in diverse fields such as agricultural, chemical, food, pharmaceutical, pulp and paper, mineral, polymer, ceramic, and textile industries. in this research actual term of electric arc heating, resistance heating, parting arc and static electrical energy were studied, and based on these factors actual vector dimensions of electron force were generated to understand the fire flash point of electron when it is in contact with solid material. this fire flash point can be used to generate heat by simple application, running on air turbulence, solid waste and firing heating furnace to use for domestic purpose. to experiment this electron fire to application level we need to take a support of fluidized bed.

1.INTRODUCTION

Fluidization is a process where a bed of loosely packed solid particles takes on some of the properties of a fluid when a gas is blown vertically upwards through it. Introducing a gas (gas-solid systems) from the bottom of a column containing solid particles via a gas distributor can cause the particles vibration and expansion in order to compensate the drag force exerted on them by the gas stream. Upon increasing the gas velocity, a point is reached at which the drag force equals the weight of the particles and the bed is said to be fluidized. Depending on the gas velocity through the bed, several flow regimes can be established. These regimes are the fixed bed, bubbling fluidization, turbulent fluidization, slugging fluidization, fast fluidization, and dilute pneumatic conveying. The transition from a fixed to a bubble-free fluidized bed is denoted by the minimum fluidization velocity, Urn1, which is the gas velocity at which the solids are just suspended in the gas stream. At very high gas flow rates, much of the solids are thrown above bed space known as the freeboard and a considerable quantity of solids is lost from the bed by elutriation and entrainment, so that gas-solid separators are required to capture a majority of these particles and return them to the bed

APPLICATION OF FLUDIZED BED IN INDUSTRY

Fluidized beds are used as a technical process which has the ability to enhance high level of gases and solids contact. In a fluidized bed a particular set of basic properties can be used, indispensable to modern process and chemical engineering, these properties are as follows:

- Surface area of contact between solid and fluid per unit bed volume is extremely high
- High relative velocities between the fluid and the dispersed solid phase.
- High particulate phase intermixing levels are high.
- Particle to particle and particle to wall collisions are frequent.

Taking an example from the food processing industry: fluidized beds are used for accelerating some IQF (Individually Quick Frozen, or freezing unpackaged separate pieces) tunnel freezer's freezing. These fluidized bed tunnels are typically used on small food products like peas, sliced vegetables or shrimp, and may utilize cryogenic or vapor-compression refrigeration. The fluid used in fluidized beds may also contain a fluid of catalytic type; that's why it is also utilized for the chemical reaction catalyzation and also for improving rate of reaction.

Fluidized beds are also used for efficient bulk drying of materials. Fluidized bed technology in dryers increases efficiency by allowing for the entire surface of the drying material to be suspended and therefore exposed to the air. This process can also be combined with heating or cooling, if necessary, according to the specifications of the application

2.LITERATURE REVIEW

R. Sivakumar, R. Saravanan, A. Elaya Perumal, S. Iniyan (2016) summarized the importance of FBD drying in combination with hybrid FBD drying techniques in moisture reduction of various agricultural products. The impact of various operating parameters on the product quality, color, texture and resultant nutritional value is discussed, with possible adaption of multi-effect systems.

S. Syahrul, I. Dincer b, F. Hamdullahpur (2002) observed that the thermodynamic efficiency of the fluidized bed dryer was the lowest at the end of the drying process in conjunction with the moisture removal rate. The inlet air temperature has a strong effect on thermodynamic efficiency for wheat, but for corn, where the diffusion coefficient depends on the temperature and the moisture content of particles, an increase in the drying air temperature did not result in an increase of the efficiency. Furthermore, the energy and exergy efficiencies showed higher values for particles with high initial moisture content while the effect of gas velocity varied depending on the particles. A good agreement was achieved between the model predictions and the available experimental results.

Wijitha Senadeera, Bhesh R. Bhandari, Gordon Young , Bandu Wijesinghe(2002) Three different particular geometrical shapes of parallelepiped, cylinder and sphere were taken from cut green beans (length: diameter ¼ 1:1, 2:1 and 3:1) and potatoes (aspect ratio ¼ 1:1, 2:1 and 3:1) and peas, respectively. Their drying behavior in a fluidized bed was studied at three different drying temperatures of 30, 40 and 50 ^{0}C (RH ¼ 15%). Drying curves were constructed using non-dimensional moisture ratio (MR) and time and their behavior was modeled using exponential (MR = exp(kt)) and Page (MR = exp(-kt^n)) models. The effective diffusion coefficient of moisture transfer was determined by Fickian method using uni- and three-dimensional moisture movements. The diffusion coefficient was least affected by the size when the moisture movement was considered three dimensional, whereas the drying temperature had a significative effect on diffusivity as expected. The drying constant and diffusivity coefficients were on the descending order for potato, beans and peas. The Arrhenius activation energy for the peas was also highest, indicating a strong barrier to moisture movement in peas as compared to beans and skinless cut potato pieces.

S. Syahrul, F. Hamdullahpur, I. Dincer (2001) conducted energy and exergy analyses of the fluidized bed drying of moist materials for optimizing the operating conditions and the quality of the products. In this regard, energy and exergy models are developed to evaluate energy and exergy efficiencies, and are then verified with experimental data (for the product, wheat) taken from the literature. The effects of inlet air temperature, fluidization velocity, and initial moisture content on both energy and exergy efficiencies are studied. Furthermore, the hydrodynamic aspects, e.g., the bed hold up, are also studied. The results show that exergy efficiencies are less than energy efficiencies due to irreversibilities which are not taken into consideration in energy analysis, and that both energy and exergy efficiencies decrease with increasing drying time

Janusz Stanisławski (2005) dried diced carrot (□90% wet basis) in a laboratory microwave fluidized-bed dryer (MFB) and in a standard fluidized-bed dryer (FB). They found that the drying time in the MFB dryer is 2–5 times shorter than in the FB dryer. Drying efficiency (DE) is a function of moisture content, microwave power and temperature of drying agent. Higher values of DE are obtained for MFB dryer. For both drying systems the water removal was proceeding in two-stage falling rate period (except short initial term).

3.EXPERIMENTAL SETUP

For present study a laboratory scale fluidized bed dryer system was fabricated. The schematic of the fabricated system is shown in Fig 3.1 mainly consisting of a fluidized bed column, electric heater and blower. Air is supplied via a root blower and then passed through a Nichrome heater. The fluidization air was supplied by a blower with flow rate measured by air flow sensor connected at the outlet of blower. The orifice plates for fluid flow in closed conduits were designed as per ASME standards. Fluidization air's temperature was measured to be approximately 40°C. This value was the steady-state discharge temperature of the blower. A 8.0% open area perforated plate with 2.0- mm diameter orifices drilled on a 6.0-mm square pitch was used to distribute the gas across the bed inlet. The air then enters the plenum filled with rings where air flow is distributed before passing through the distributor plate. The distributor plate is constructed from cast iron of 6 mm thickness, with 25 holes of 2 mm diameter arranged in a triangular pattern, resulting in 8 % free area. The pressure drop across the distributor plate and the bed was measured by another differential transducer.
The bed pressure drop was measured across the freeboard and 3 cm above the distributor plate. The measurements of pressure drop were collected at 400 Hz. This is to ensure that all frequencies relevant to the analysis of the hydrodynamics are captured. The data was displayed in an LCD display unit attached to the system. And readings were tabulated at regular interval of time.

The cylinder bed column is made of Cast iron with 7mm wall thickness, 175mm internal diameter with overall length of 1200 mm. Digital thermometers were used to measure the temperature at inlet and outlet of the bed as well as locations at 20, 40, 60, 110, 150, 160 and 700 mm above the distributor plate. The wall temperature was measured at 60 mm above the distributor plate on the inner side of the column. All digital thermometers were same type and specifications are given in Table 3.1.

The relative humidity of exit air was measured by using humidity transducer located before the exit. It is calibrated using solutions with different vapor pressures and equilibrium relative humidity. The specifications of relative humidity are given in Table 3.2.

Table 3.1 Specifications of digital thermometers

Type	Material	Probe Diameter	Maximum Temperature	Length	Junction Type
DS18B20 digital thermometer	High quality stainless steel tube encapsulation	1/8 inch	125^0 C	4 inch	enclosed

Table 3.2 Specifications of humidity transducer

Type	RH-Range	Temperature	Accuracy	Sensor	Output Signal
DHT11	20-90%	0-50^0C	$\pm 5\%$ RH	DFRobot DHT11	4-20 mA

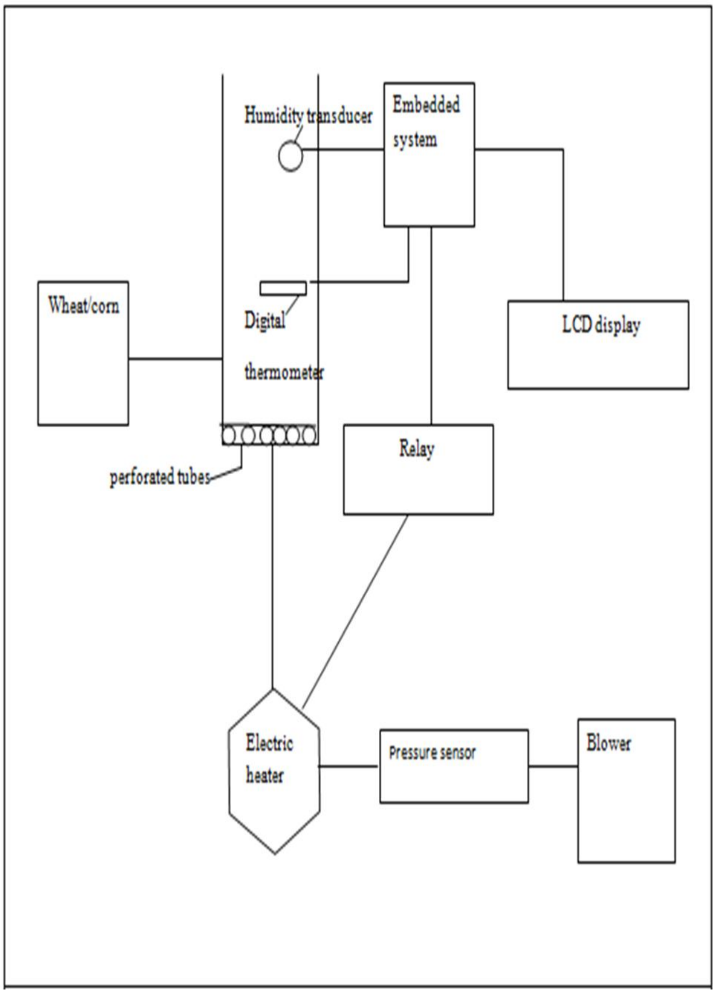


Figure 3.1: Schematic Diagram of experimental setup

3.1 The Heater

An electric heater is used to heat inlet air to the desired temperature. A Nichrome heater coil supplied with a constant current is attached in an insulated sheet metal furnace. The inlet air temperature is continuously sampled and compared with the set value temperature, and depending on the comparison, the power supply to the heater is adjusted through the solid state relay.

3.2 The Balance

A digital balance is used to measure the weight of the samples during the experiment runs. The accuracy of the balance is 0.0001 g. The maximum admissible weight of the balance is 160 gm.

3.3 Data Acquisition System

The entire signal from digital thermometers, pressure transducers, and humidity transducers are displayed in the display unit attached to the system. Readings are recorded at a proper interval of time for further analysis.

4.MATERIAL PROPERTIES

4.1 Wheat

Red-spring wheat was used as one of the test materials. The wheat is approximately ellipsoidal in shape with a thread in the direction of longer diameter. In this study, however, for simplicity the numerical solution of the wheat is assumed to be spherical with an average diameter of 3.66 mm and density of 1215 kg/m^3.

4.2 Corn

Second material used for the drying test was shelled corn. The corn kernel is found to have a shape factor close to the unity with an average diameter of 6.45 mm and the density of 1260Kg/m^3

5.METHOD OF GRAIN CONDITIONING

The grains taken for the experiment had moisture content of 10-18% on a dry basis initially. In order to raise the moisture content to 21-40% and simulate condition of newly harvested grain water was added to the material. The conditioning procedure used in this work was carried out by filling a plastic bucket with necessary amount of grain. The calculated amount of water was added to raise the moisture content to the desired value and at the same time the grain was mixed with a mechanical agitator. The grain was stored at room temperature for 48 hours with repeated mixing at periodic intervals. The bucket of the grain is then stored in a refrigerator at 5-7 degree centigrade until drying time to prevent degradation or germination of the grain. Generally, the storage time was 5 days and after that sample was used in the experiment.

It should be noted that the lost bed mass due to drying was not made up between moisture content experiments. Although these changes are considerable, minimum fluidization velocity and bed voidage are particle properties and therefore not influenced by bed mass.

6.MOISTURE CONTENT DETERMINATION OF THE GRAIN

Before starting experiment moisture content of the grains were determined. The moisture content of the grain was determined by a standard method developed by American Society of Agricultural Engineers, ASAE standard: S352.2. Table 3.3 shows the sample weight and temperature and time of drying.

Table 3.3: ASAE standard for drying of the grains

Grain	Weight of Sample	Temperature(±^{0}C)	Drying Time
Wheat	10 g	130	19 hours
Corn	15 g	103	72 hours

Weight of the dry gains was taken before and after conditioning for determination of the moisture content of the gain. All moisture content refer to in this work are on a dry basis. The moisture content on a dry basis is calculated by:

$$M_P = \frac{W_B - W_A}{W_A} \quad \ldots\ldots\ldots (1)$$

W_B= Weight of grain before drying
W_A= Weight of grain after drying

M= Moisture content of a grain on a dry basis
The moisture content on a wet basis is given by

$$M_{PWB} = \frac{M_P}{1+M_P} \quad \ldots\ldots\ldots\ldots (2)$$

7.Methodology

Initial moisture content of the sample was determined before drying. In order to attain a uniform working condition, hot air is blown through the bed for one hour before charging with the material. The air supply and power to heater was turned off as bed reached required temperature, the material was charged into bed as quickly as possible. The air supply and heat power is then reinstated and the pressure drop across the distributor and the bed at the corresponding gas velocity was measured. Temperature, pressure, humidity, and velocity are taken continuously at regular interval of time through LCD display attached to the system. Since the digital thermometers and the humidity transducer were exposed to hot air before the start of the drying process, there might be some experimental errors in the initial reading of them.

8.Data Analysis

An air flow sensor (HZ21WA) was used in measuring pressure fluctuation data. Inlet of the sensor was connected to the outlet of root blower and outlet of the sensor was connected to the inlet of heater coil. For recording the data of digital thermometer, humidity transducer, and pressure sensor an LCD display was attached to the system.. All raw data sets collected were at the sampling rate of 400 Hz. This data was subsequently filtered offline using a type 1 Chebychev band-pass filter design in Matlab between 0.5 Hz and 170 Hz. Filtering was performed in order to fulfill the Nyquist criterion as well as to eliminate low frequency transitory effects associated with the piezoelectric sensor.
The S-statistic algorithm of van Ommen was implemented in Matlab. Along with the S-statistic, each pressure time series was examined for changes in frequency and intensity. Only a single bubbling or dominant frequency was examined in this study. To determine this frequency, the power spectral density was calculated for each data set in Matlab. This spectrum's maximum peak frequency was selected as the dominant frequency. Standard deviation was calculated in the usual way for a sample drawn from a population.

Results

Two different materials were used in the drying experiment to obtain the complete experimental data. During the drying process of the grains certain observations were made which are tabulated below.

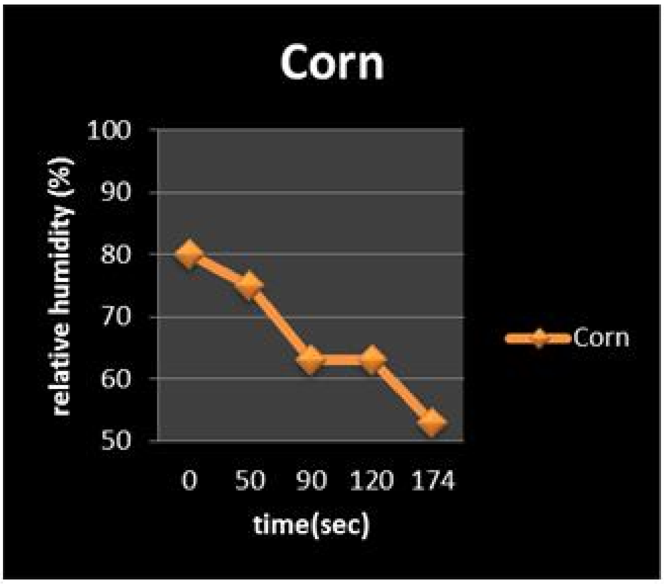
VALUES	TEMPERATURES				
	20^0 C	30^0 C	40^0 C	50^0 C	70^0 C
Time (sec)	0	50	90	120	174
Relative Humidity	80%	75%	63%	63%	53%
Pressure (psi)	0	8	9	9	10

Results Obtained For Corn

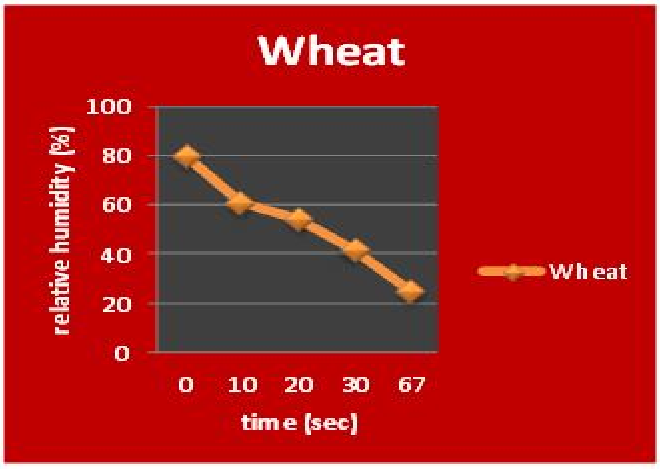
VALUES	TEMPERATURES				
	20^0 C	30^0 C	40^0 C	50^0 C	70^0 C
Time (sec)	0	15	30	40	67
Relative Humidity	80%	61%	54%	42%	25%
Pressure (psi)	0	8	8	8	13

Results Obtained For Wheet

In the above tables results obtained for the wheat granules are summarized. The analysis of the result showed that the rate of moisture loss was fast at the beginning when the moisture was at the surface of the grain but as we get inside the grain the rate of moisture transfer decreases. But when compared to corn the rate of moisture transfer was greater as the size of Corn is greater than wheat.

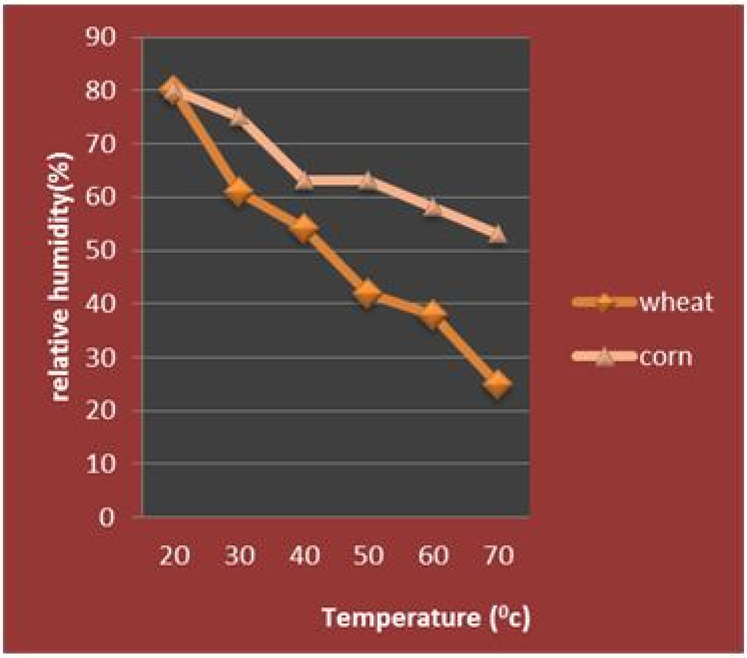


Graph of Time vs. Relative Humidity for Corn



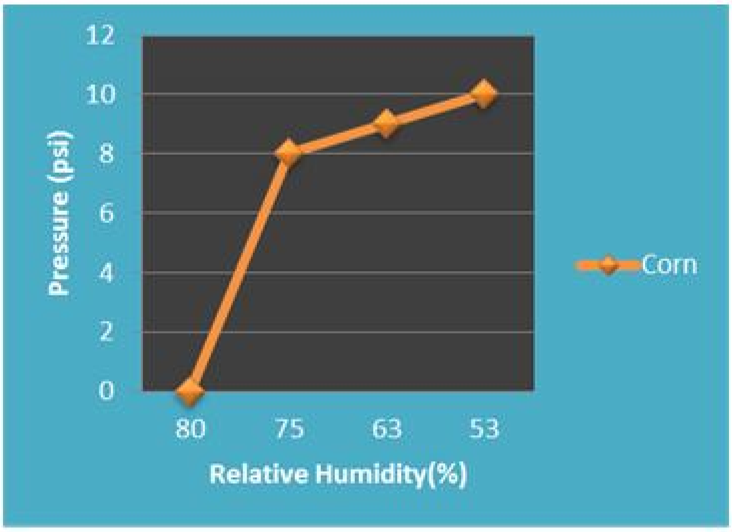
Graph of Time vs. Relative Humidity for Wheat

Graph shown above shows a relation time and relative humidity for corn and wheat. It's clear from the graph for corn that the rate of drying is faster at the beginning but gradually it decreases. While on the other hand rate of drying is steady throughout time for corn. This is because of the even surface of the wheat and also smaller particle size.



Relationship between Temperature and Relative Humidity for Grains

A relationship between the temperature and relative humidity for wheat and grains is shown in Graph 4.3. As it is evident from the graph for the same temperature range of the rate of drying for the two grains is very different. While in the case of wheat there was loss of about 70% in the relative humidity while decrement in the relative humidity for the same temperature range in case of corn was only about 37.5%.



Graph of Pressure vs. Relative Humidity for Corn

From the above and next graph we can deduce that the pressure of fluidized air also plays an important role in the drying of grains as we can see above that when the pressure of the fluidized air is kept constant the rate of drying of grains remain steady but as we increase the pressure of the air the rate of drying also increases.

Graph of Pressure vs. Relative Humidity for Wheat

9.CONCLUSION

The fluidized bed setup was fabricated for drying of grains. In order to verify the applicability of the models, the experimental drying data of wheat for different operating conditions were employed. Also, various aspects of fluidized bed drying process of moist particles, such as the inlet air temperature, the inlet air (gas) velocity, the initial moisture contents of the material and the bedmhold-up period are investigated

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