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Evaluation Of Residence Time For Drying Of Wet Bagasse In A Rotary Bagasse Dryer Used In Jaggery Plant.

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Abstract : *In this paper, the rotary bagasse dryer was analyzed by measuring the drying rate for different input conditions. Bagasse is the main raw material obtained during the production of jaggery. In jaggery unit, bagasse is dried in a area under open sky. The residence time is around 4 to 6 days and involved 7 to 10 workers. In spring season we cannot run the plant because of bagasse cannot be dried in open sky. Bagasse can be dried effectively by incorporating the rotary dryer in jaggery plant. The flue gas heat rejected to chimney is utilizes to dry the bagasse by incorporating the rotary dryer. The results obtained experimentally for the average residence time was compared to results obtained from mathematical model are presented in this paper. It is a good compliance with the experimental data of residence time with theoretical results.*
***Keywords** - Bagasse ,Rotary dryer ,Residence time , Jaggery plant.*

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I. INTRODUCTION

1.1 Bagasse is the raw material obtained after extraction of juice from sugar cane. It is used as a fuel in jaggery plants for boiling sugarcane juice. It is dried in open area under sunlight. For sufficient drying, it requires few days and involve 7 to 10 worker for spreading and collecting the bagasse. In sun drying, complete removal of moisture is not possible. In spring season jaggery unit cannot be run, because of bagasse contains more than 50% moisture. In rainy season, it needs to shut down completely. The wet bagasse cannot be burn effectively and jaggery unit can't run efficiently.

1.2 The completely dried bagasse consists of 38-40% Cellulose, 25-28% Hemi-cellulose, 20-22 % Lignin, 2-3% Sucrose and 7-10 % of ash [1,13]. Drying, being one of the most energy intensive process is of most importance. Rotary drums are often used for drying in many industries such as fertilizer, cotton seed and biomass drying. Same dryer can be efficiently applied to dry the bagasse.

1.3 Rotary dryers are commonly used in the process industry to dry the solid, paste and granular materials [2]. The rotary dryer consisting of long cylindrical drum that is rotated on four bearing. The drum is slightly inclined at an angle of 40 to 50 to the horizontal. This inclination leads to solids flow from inlet to outlet end by gravitation.

1.4 The rate of drying in rotary drying mainly depends on nature of motion of solids and gas–solid contact. In rotary dryer, heat transfer rate enhanced by introducing flights in drum, placed parallel along the length of the drum. The flights lift the solids and suspend them across the section of the dryer from different position of drum. The movement of solids throughout the drum takes place by cascade motion of solid in the drum. The design and selection of the patterns of flights promotes good gas-solid contact makes more rapid and homogeneous drying.[3,14].

1.5 Rotary dryer is consisting of flights which lifts the bagasse and suspends it from different position of drum Fig (1). In rotary dryer the moment of bagasse takes place by three means[4].

Fig.1 Rotary Drum with Five Flights used for Drying Bagasse.

1 The bagasse moves downward due to gravitational force. The drum is inclined in forward direction.
2 The flights lift the bagasse and suspend it from different portion of the drum.
3 The flue gas drags the bagasse in forward direction.

II. MATHEMATICAL MODEL

2.1 It has been discussed about movement of particles in rotating drum [5]. It depends on of flights and shell design as well as on the operating conditions. The motion of material is most complex in rotary dryers, and thus having one of the most challenges job to formulate the mathematical model for rotary dryers.

2.2 Many authors have developed mathematical model for rotary drying. It has used to predict the solar drying of bagasse pulp [6]. They tried to develop a model, which was used in solar energy drying. They obtained the mathematical equation for drying rate for natural convection and forced hot air convection. It has been made study of particle motion in the rotary dryer [7]. They have developed mathematical model for residence time, number of flights and their effect on the drying rate of the materials. They have discussed about dynamic coefficient of friction and hold up time and length of fall of drying materials. One of the most frequently used empirical relation to calculate the residence time for granular materials was proposed by Friedman and Marshall [2, 3, 8].

$$\tau = L\left[\frac{0.3344}{\alpha N_R D} \pm \frac{0.608G}{W d_P^{05}}\right] \qquad (1)$$

In equation (1) Negative sign is used for gas is having concurrent flow with drying material and positive sign is used when the gas flow is in countercurrent direction of drying material flow.

2.3 Saeman and Mitchell were the first to derived mathematical model for residence time in rotary dryer. They analyzed material transport rates associated with individual cascade paths to yield a transport rate distribution function. They derive the following equation for average residence time[9].

$$\tau = \frac{L}{f(H^*) D N_R (\tan\alpha \pm M' V)} \qquad (2)$$

The another model was proposed by Perry and Green which helps to calculate average residence time[10].

$$\tau = \frac{K_p L}{D N^{0.9} \tan\alpha} \qquad (3)$$

S.H. Shahhosseini has modified the model used to predict residence time of solid proposed by Friedman and Marshall and incorporated the different parameters in the model [11]. It has given mathematical correlation of residence time of rotary kiln without flights [12].

$$\tau = \frac{106.2 L \sqrt{\gamma}}{N D \tan\alpha} \qquad (4)$$

Where γ is the natural angle of repose of the material, which increase when the material is more cohesive and less for free flowing. Jouhari and Dey have given an equation based on work done by the U.S Bureau and Mines.

$$\tau = \frac{1.77L\sqrt{\gamma k_f}}{ND\alpha} \quad (5)$$

The above equation is similar to Sullivan's Kiln equation. The factor k_f is used, when there are no flights and obstacle weirs to flow of gases.

All above models are developed to predict the residence time of granular materials. The results obtained in our experiment are not agreed with above models. In this experimental work, it has been used mathematical model developed by the Saeman and Mitchell to predicted the residence time of bagasse in rotary dryer. The value of cascade constant $f(H^*)$ and M' is not selected form range given by the author. The value of $f(H^*) = 0.013$ and $M'=2$ are selected for our theoretical prediction of residence time.

2.4 The values of the constants are changed because of following reasons.

1 Saeman and Mitchell have developed the model to predict the residence time of dryer used to dry the granular materials.

2 The motion of granular material is faster as compare to bagasse.

3 The particles size of bagasse is not uniform.

4 The physical properties of bagasse are entirely different from the granular materials. So modifications are made in below model.

$$\tau = \frac{L}{f(H^*)DN_R(\tan\alpha \pm M'V)} \quad (6)$$

III. EXPERIMENTAL WORK

3.1 Experiments were conducted in Jaggery plant by installing full scale model of rotary dryer. Fig.[2] shows rotary drum type dryer which is fabricated in Suresh Engineering Pvt Ltd , MIDC Kupwad ,Sangli. The rotary dryer is having drum of 9 meters long and 1.2 meter diameter. The speed of rotary drum is kept constant and equal to 5 rpm.

3.2 The drum is having five flights inside it and equally spaced. The flights are fitted at different angular positions at every 3 meters distance in the drum.

Fig 2. Jaggery Plant with Rotary Bagasse Dryer.

3.3 In Fig. [3] Shows, wet bagasse is fed into the hopper, which conveyed from the mill to hopper. The bagasse enters the rotary dryer. The flue gases are conveyed to dryer through duct with the help of FD fan. The rotary drum is driven by electrical motor having 3.5KW capacity. A reduction gear box was used to reduce the speed of motor of 1460 rpm to 5 rpm of drum. Different parameters were measured. Inlet and outlet temperatures were measured with the help of pressure thermometer. The digital anemometer was used to measure flue gas velocity. Digital moisture meter was used to measure inlet and outlet moisture of bagasse. The feed rate of bagasse was almost kept constant throughout the experimentation. Residence time was measured by feeding colored bagasse and measuring the time require to travel the same. The velocity of flue gas is measured, at the inlet of dryer, by using digital anemometer. In order to maintain constant temperature of the flue gases, the fuel supplied to furnace was controlled. For certain percentage of inlet gate opening, all parameters were measured simultaneously.

3.4 The rate of bagasse flow in drum was 10 kg/min. The rate of flow of flue gas was controlled by percentage opening of inlet gate. The moistures in the bagasse at inlet and at outlet of dryer were measured by using digital moisture meter.

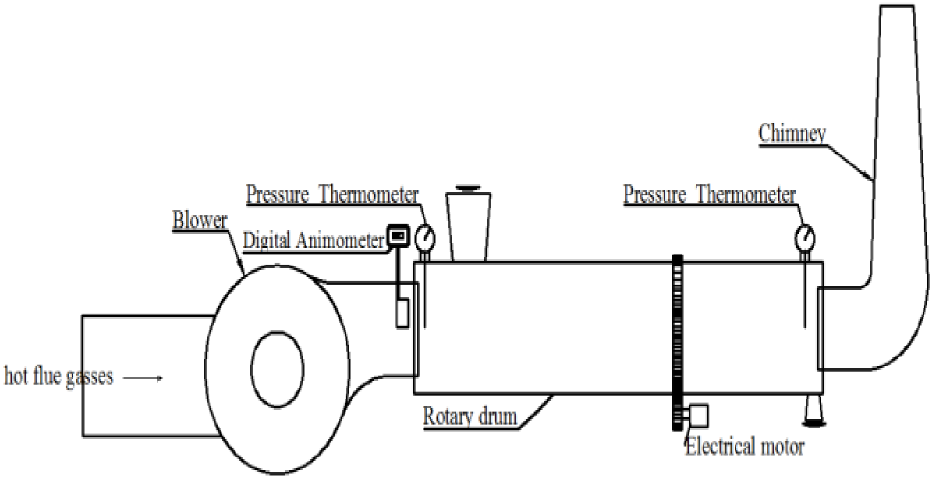

Fig. 3 Schematic diagram of Rotary Bagasse Dryer.

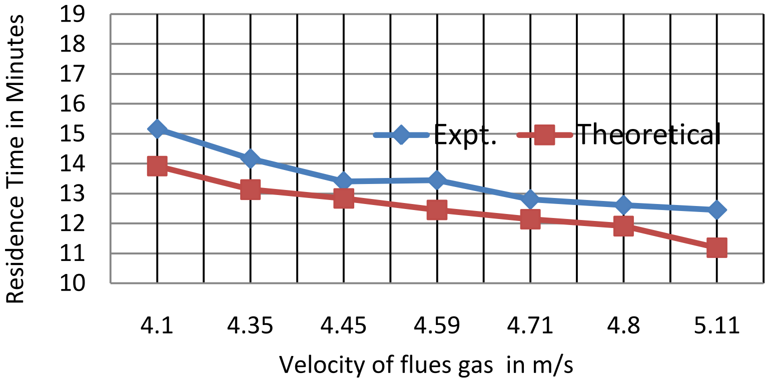

Fig. 4 Comparison of theoretical and experimental residence time.(Inlet Temp-200 to 210^{0}C)

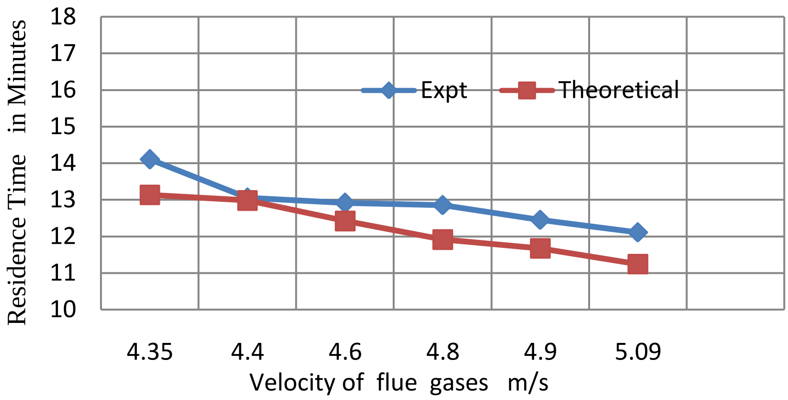

Fig.5 Comparison of theoretical and experimental residence time. (Inlet Temp-220 to 230^{0}C)

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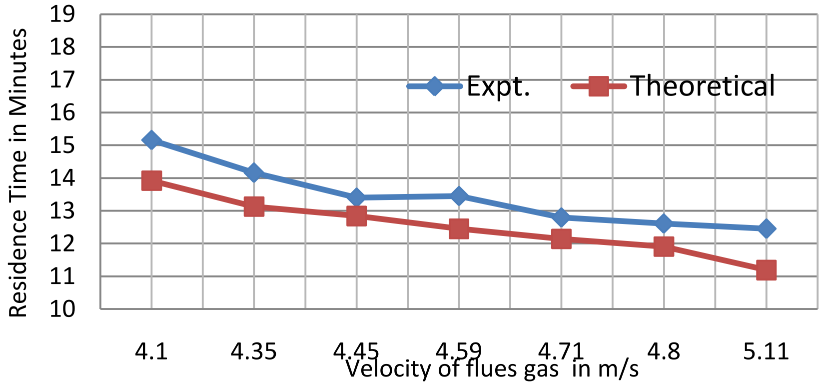

Fig 6. Comparison of theoretical and experimental residence time. (Inlet Temp-240 to 260^{0}C)

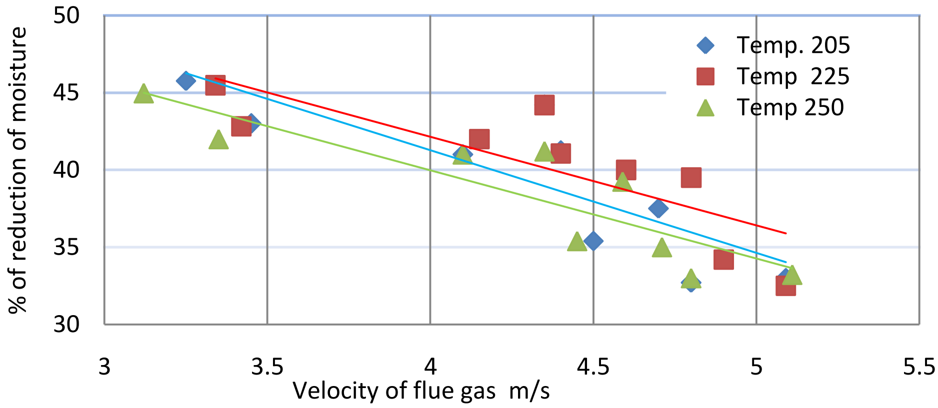

Fig.7 Velocity of flues gas versus % residence time.

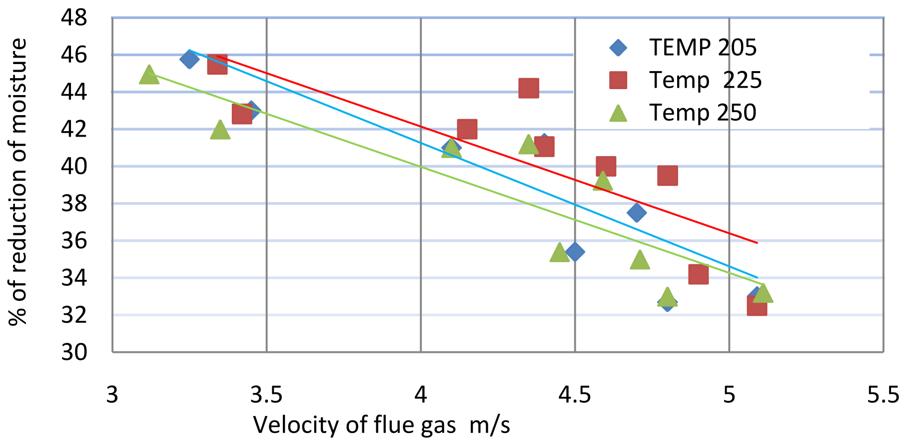

Fig. 8 Velocity of flues gas versus % Reduction of Moisture.

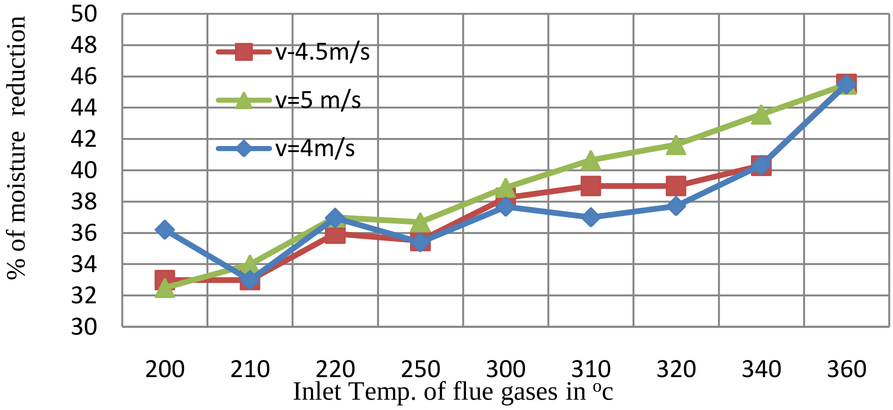

Fig. 9 Temperature flues gas at inlet versus % Moisture reduction.

IV. Results And Discussion

4.1 The moisture reduction rate is directly depends on the inlet temperature. The moisture reduction rate is almost linearly varying with respect to inlet temperature. As temperature increases behind the 350^0c, the moisture will remove in large quantity but the quality of bagasse will be diminished. This tends to partial burning of bagasse and ultimately calorific value of bagasse reduced. So the temperature range should be in between 250^0c to 350^0c. In this range the output quality of bagasse is good enough to give maximum calorific value.

4.2 The residence time is an important parameter which directly influence the remaining moisture contain in the bagasse. As residence time increases the percentage of moisture content is reduced.

4.3 Both temperature and high residence time leads to increase in the quality of bagasse. When residence time is minimized, then quality of bagasse will reduce .The residence time mainly depend on number of parameter such a number of flights, inclination of drum, velocity of flue gases, speed of drum and nature of drying materials. In our test the drum speed, angle of inclination, number of flights and feed rate of material are kept constant. The only varying parameter is velocity of flue gases and inlet temperature. Bagasse can be dried effectively and economically in rotary dryer by proper control of inlet temperature and velocity of flue gases. The rotary dryer can be incorporate in jaggery plant most effectively.

4.4 The mathematical model developed by the Saeman and Mitchell used to predict the experimental results. The experimental results obtained are well agreed with the theoretical results calculated by using Saeman and Mitchell model.

4.5 The Fig. no. 4 to 6 express, the predicted value of residence time calculated by using Saeman and Mitchell model and experimental results are well agreed.

4.6 The Fig. no.7 represents velocity of flue gases influence the residence time. As velocity increases residence time will reduce.

4.7 The Fig. no.8 indicated that, velocity of flue gases affect the percentage of moisture reduction.

4.8 The Fig no.9 reveals that, the inlet temperature of flue gases affect the moisture reduction.

V. Conclusion

The rotary dryer can be incorporate in jaggery plant. The rotary bagasse dryer which was fabricated in local industries can be employ to dry the bagasse effectively. The results obtained from the bagasse dryer are good enough to dry the bagasse. The use of bagasse dryer in jaggery plant will reduce the man power required to handle the bagasse. The bagasse dryer reduce the human hazards. The overall human effort is reduced in large extent.

Symbols and abbreviations

D	Drier diameter, m.	N	Flights number.
d_p	Average particles diameter, microns.,	N_R	Rotation speed, rpm
f (H*)	Parameter related to the drier load	v	Gas-particle velocity, m/s.
G	Gas flow; m^3/min.	W	Solids flow, kg/min.
k_f.	Constant when there is no flights.	α	Drier inclination, rad.
K_p	parameter that depends on the number and format of the flights.	τ	Residence Time , Min.
L	Drier length, m.,	γ	Natural angle of repose of the material.

M' Empirical parameter for given material.

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