Performance Analysis of Rotary Cotton Seed Dryer

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***Abstract* - Drying is perhaps the oldest and most commonly used technique in the processing of the cottonseeds for extracting the cottonseed oil and cottonseed meal of good quality. The cotton seed contains about 17-18% of moisture by weight, and it must be dried only up to 6-7% of moisture inherent in it.**

For accomplishing the above purpose, the convective type of dryer is used. The dryer is named as 'Rotary Cotton Seed Dryer' For the enhancement of performance of the dryer, the effect of operating variables mass flow rate of air & inlet temperature of air on shrinkage ratio, specific energy consumption (SEC) and pick-up efficiency are to be studied in this work.

***Keywords* - Cotton seed dryer, humidifying efficiency and moisture content.**

INTRODUCTION

'Cotton' the white gold is one of the most important commercial; crops playing a key role in the economical, political and social affairs of the country. Successful cultivation of cotton requires plenty of sunshine and a moderate rainfall; usually from 600 to 1200 mm. Soils usually need to be fairly heavy, although the level of nutrients does not need to be exceptional. In general, these conditions are met within the seasonally dry tropics and subtropics in the Northern and Southern hemispheres, but a large proportion of the cotton grown today is cultivated in areas with less rainfall that obtain the water from irrigation. The largest producers of cotton, currently, are China and India, with annual production of about 33 million bales and 27 million bales. In India, the states of Maharashtra (26.63%), Gujarat (17.96%) and Andhra Pradesh (13.75%) and also Madhya Pradesh are the leading cotton producing states. These states have a predominantly tropical wet and dry climate [2].

Cotton is used to make a number of textile products. These include terrycloth for highly absorbent bath towels and robes; denim for blue jeans; cambric, popularly used in the manufacture of blue work shirts (from which we get the term "blue-collar"); and corduroy, seersucker, and cotton twill. Socks, underwear, and most T-shirts are made from cotton. Bed sheets often are made from cotton.

The cottonseed which remains after the cotton is ginned is used to produce cottonseed oil, which, after refining, can be consumed by humans like any other vegetable oil. The cottonseed meal that is left generally is fed to ruminant livestock. Cottonseed hulls can be added to dairy cattle rations for roughage.

PROBLEM DEFINITION

As already discussed one of the byproduct of cottonseed is cottonseed oil, which can be used for several purposes. Cottonseeds contain 17-18% moisture in it. Cottonseeds need to be dried before oil extraction process. Oil extraction from wet cottonseed will result in extraction of poor quality oil and Slurry of waste material instead of good hard oilcake. Therefore moisture content of cottonseed needs to be reduced to 6 -7%. Most simple and economic way of drying cottonseed is open sun drying, which is still used by some of the small scale oil mills. But this process is very time consuming and needs large ground area. One other way is to use dryer, which allows hot air to pass over cottonseed and carry away the moisture in cottonseed.

Most of the small scale oil mills generally use bed type dryers for drying cottonseed. In bed type dryer hot air is passed over thick bed of cottonseed. But as seeds are not exposed to hot air from all sides, bed type dryer requires more amount of hot air. Also seeds which forms wall of the bed will be in direct contact of hot air, so these seeds will dry faster as compared to seeds which are in middle portion of bed. As a result non uniform drying of seeds takes place.

This problem of non uniform drying can be solved by using rotary dryer. Rotary dryer consist of rotating drum having flights on its inner periphery. Cottonseed will be fed into drum. As drum rotates flight will carry cottonseed with it and toss them in the air. Hot air will be blown from one end of drum. As seeds will be air borne after tossing up they will be surrounded by hot air from all side. This will enhance heat transfer from hot air to seed. When seeds reach to the other end of drum they will be at higher temperature. Some amount of the moisture in the seed is removed during its heating in drum while remaining amount will be removed during cooling of seed outside drum.

OBJECTIVE

Performance of rotary dryer depends on number of flights, speed of rotation of drum, mass flow rate of air, inlet temperature of drying air. So, Objective of this work is to analyze rotary cottonseed dryer and study the effects of following factors on shrinkage ratio, specific energy consumption and humidifying efficiency.

1. Inlet air temperature.
2. Mass flow rate of air

Drying Equipment

Drying of cottonseeds is to be analyzed in rotary drum type dryer. It has horizontal drum having radius of 0.6 m and length of 7.5 m. Drum has flights attached to its inner periphery which were useful for tossing of seeds inside drum. Air was supplied with the help of insulated ducting and air flow is to be controlled by using valve. Air is to be heated by using hot air generator. This hot air is to be passed over seeds in drum which will continuously rotate with the help of 3 phase electric motor. Speed of the motor can be controlled with variable frequency drive. Power of the motor is to be transmitted to drum through reduction gear box and chain drive. During experiments temperature, relative humidity of air at ambient, at inlet and outlet of drum are to be recorded.

EXPERIMENTAL SETUP

The rotary cotton seed dryer whose performance is to be analyzed is as shown in fig.

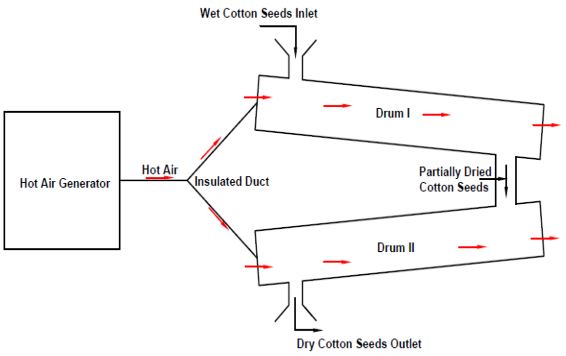


Fig. Block Diagram of Rotary Cotton Seed Dryer

Fig Experimental Setup of Rotary Cotton Seed Dryer

The main components of dryer are:

1. Hot air generator: - Hot air generator is used for producing hot air required for drying purpose. The hot air is produced by using wood fired hot air generator.

2. Hopper: **-** It is utilized for pouring wet cotton seeds and for extracting dry cotton seeds as shown in fig.

3. Insulated drum I: **-** Drum I is insulated device in which drying is carried out with the help of hot air. This drum is continuously rotating in clockwise direction about horizontal axis. In drum I, initial wet cotton seeds are enter through hopper and after partial drying the outcome is transferred to the drum II for further drying process.

4. Insulated drum II: **-** Drum II is insulated device in which remaining drying process is carried out with the help of hot air. This drum is also continuously rotating in clockwise direction about horizontal axis. In drum II, partially dried cotton seeds from drum I are enter through insulated pipe and after complete drying the outcome is extracted from the system to the surrounding through hopper as shown in fig.

5. Insulated duct: - Insulated duct is used for transferring hot air from hot air generator to the drum I and drum II as shown in fig.

EXPERIMENTAL PROCEDURE

Experiments were conducted on drying of cottonseed on experimental setup described above. The following steps are to be followed for fulfillment of our objective:-

1) Initially, the weight of the cotton seed was recorded before allowing it for drying.
2) Setup was run empty for 1.5 hours in order to get drum to steady state.
3) Drum was loaded with wet cotton seed as per design load.
4) Dryer was run for 20-30 minutes so as to attain steady state. Ambient air temperature and relative humidity, inlet air temperature and outlet air temperature was recorded.
5) After that, drum was unloaded with the help of roller conveyer mechanism.
6) After completion of drying process, the weight and moisture content of cotton seed was recorded.

Performance of dryer is evaluated from shrinkage ratio (SR), specific energy consumption (SEC), and humidifying efficiency (η_{hum}).

Shrinkage ratio is nothing but ratio of weight of seeds after drying for 20 minutes to initial weight of seeds. It is given by Eq. (1)

$$SR = \frac{M_{pf}}{M_{pi}} \qquad (1)$$

Specific energy consumption (SEC) which is also termed as moisture extraction rate (MER) is defined as the power supplied for heating air in kW-h divided by the mass of water evaporated from the seeds. The dryer is better performing if it has a lower SEC.

$$SEC = \frac{M_a C_a (T_{ai} - T_\infty)}{\Delta M_p} \quad (2)$$

Where, M_a is the mass of dry air in Kg
C_a is the specific heat of air in KJ/Kg K
T_{ai} is the temperature of inlet air in K
T_∞ is the ambient temperature K
ΔM_p is the mass water vapour evaporated
$\Delta M_p = M_{pf} - M_{pi}$
Mass of dry air computed by using relation as below:

$$Ma = \frac{(1.0132 - P_v) \times \dot{V}_a \times t}{R \times T_\infty} \quad (3)$$

Where, P_v is Partial pressure of vapour = $\phi_\infty \times P_{vs\infty}$

$P_{vs\infty}$ is Saturation pressure of vapour at $T\infty$,

R is universal gas constant = 287 J/Kg K

The specific heat of air was obtained by eq. (4)

$$C_a = 1.005 + 1.88w \quad (4)$$

Where w is the humidity ratio of the air. Following equation was used to transform relative humidity to humidity ratio.

$$w = 0.622 \frac{\varphi P_{vs}}{P - \varphi P_{vs}} \quad (5)$$

Where, ϕ is relative humidity of air
P_{vs} is saturation pressure
P is ambient pressure.

Humidifying efficiency of the dryer is defined as ratio of dry bulb temperature decrease to the entering wet bulb depression. It is also known as saturating efficiency. It is given by equation (6)

$$\eta_{hum} = \frac{T_{ai} - T_{ao}}{T_{ai} - T_{dba}} \quad (6)$$

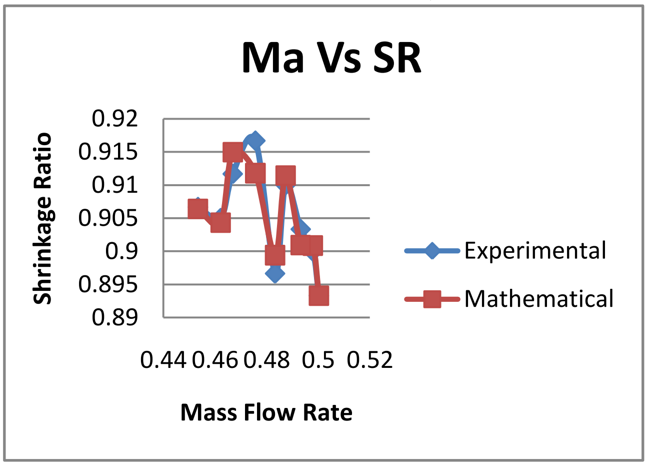
Where, T_{ai} is DBT at inlet of the drum
T_{ao} is DBT at outlet of drum
T_{dba} is temperature corresponding to cooling and humidification process during which enthalpy remains constant.

PERFORMANCE ANALYSIS

In performance analysis, the comparison between mathematical results and experimental results is done which are as follows:

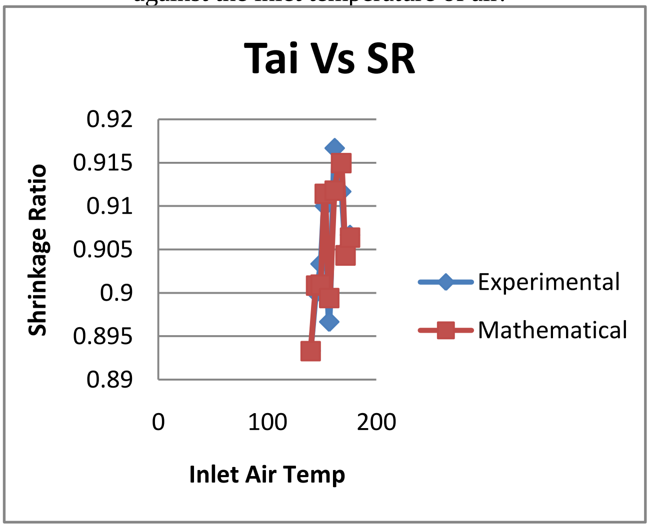
Comparison of Shrinkage Ratio

Following graph the variation of shrinkage ratio against the mass flow rate of air.



Graph 1 Experimental and Mathematical (Predicted) Shrinkage Ratio against mass flow rate.

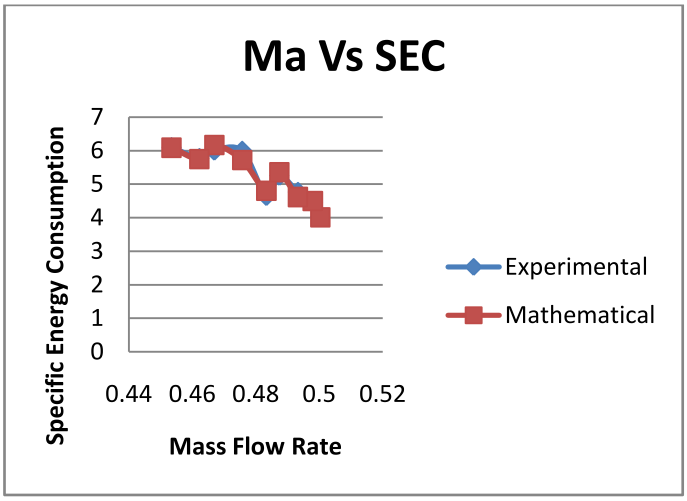
Following graph shows the variation of shrinkage ratio against the inlet temperature of air.



Graph 2 Experimental and Predicted Shrinkage Ratio against inlet air temperature

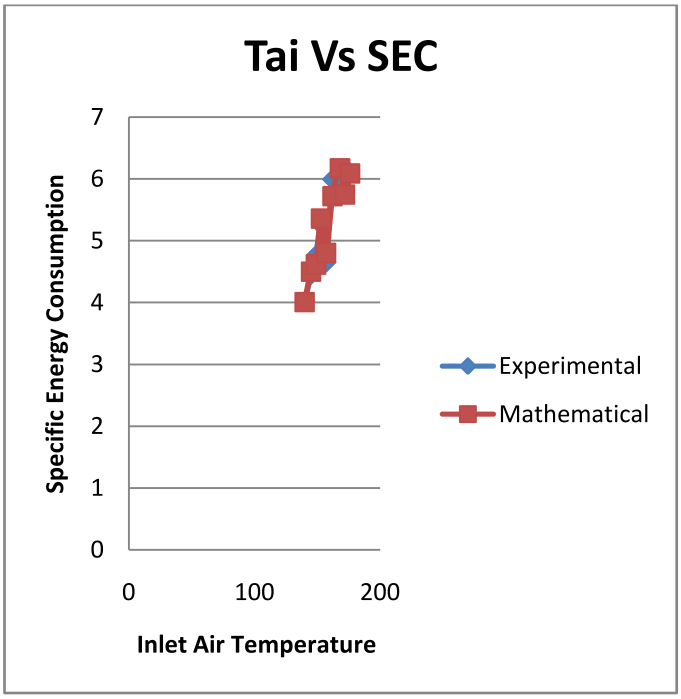
Comparison of SEC

Following graph the variation of specific energy consumption against the mass flow rate of air of air.



Graph 3 Experimental and Mathematical (Predicted) SEC against mass flow rate.

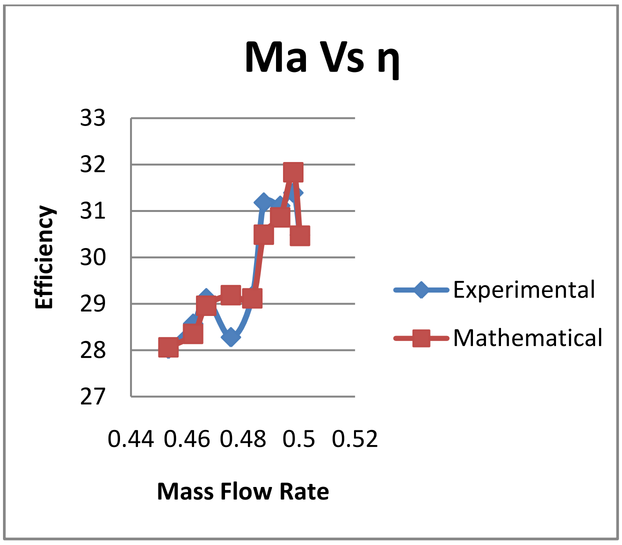
Following graph shows the variation of specific energy consumption against the inlet temperature of air.



Graph 4 Experimental and Mathematical (Predicted) SEC against inlet air temperature.

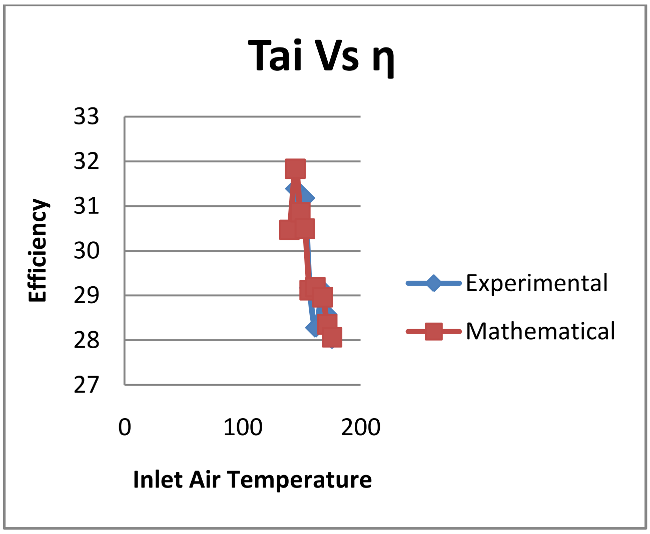
Comparison of Humidifying Efficiency

Following graph shows the variation of humidifying efficiency against the mass flow rate of air.



Graph 5 Experimental and Mathematical (Predicted) humidifying efficiency against mass flow rate

Following graph shows the variation of humidifying efficiency against the inlet temperature of air.



Graph 6 Experimental and Mathematical (Predicted) humidifying efficiency against inlet air temperature.

CONCLUSION

Performance analysis of cottonseed drying in rotary dryer was done in this work. Significant amount of moisture was removed in short time of 20 minutes. Following conclusions are made from performance analysis

1. Shrinkage Ratio increased with increase in mass flow rate of air.
2. Shrinkage Ratio increased with increase in inlet temperature of air.
3. Specific Energy Consumption increased with increase in mass flow rate of air.
4. Specific Energy Consumption increased with increase in inlet temperature of air.
5. Humidifying Efficiency increased with increase in mass flow rate of air.
6. Humidifying Efficiency decreased with increase in inlet air temperature.
7. From graphs it is clear that the results obtained from mathematical analysis and experimental analysis are nearly same.

APPLICATIONS

1. Rotary cottonseed dryer can be extensively used in oil mills to remove moisture from seeds before oil extraction process.

2. Moisture content of seeds needs to be reduced for storing purpose also. For these purpose also rotary cottonseed dryer can be used.

FUTURE SCOPE

Performance of dryer mainly depends on inlet air temperature, mass flow rate of air and drying time. Selection of these factors depends on the moisture content of seeds, ambient temperature and relative humidity which may vary with each batch. So, automatic system can be developed which will control the flow rate and temperature of drying air.

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