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Effect of Insulation on Rotary Drum Dryer's Performance

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Abstract

This paper is about the rotary drum cotton seed dryer. Here in this research work one experiment was taken on the drying mechanism of the cotton seeds in rotary drum type dryer. For this experimentation one setup was assembled and performance of the dryer was checked in the form of amount of moisture extracted from the seeds. This performance estimation was done with and without the insulation of the surface area of the drum. Also these experiments were done for different mass flow rate and different temperature of the heating air. After analyzing these experimental results, it was found that the moisture extraction rate goes on increasing with the increase in the air flow rate and temperature. It was concluded at the end that the best performance was observed at peak temperature and peak flow rate of air, with insulation. The graphs mentioned in this paper will clear the results and observations.

Keywords: cotton seeds, rotary drum dryer, dryer insulation, dryer performance.

Introduction

Drying is perhaps the oldest and most commonly used technique in the mechanical industries. One such main use of the drying process is 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 remains in it.

Basically drying is done by vaporising the moisture of wet feedstock, by supplying heat to it. Heat may be supplied by three common means *i.e.* convection, conduction, and radiation, or by placing the wet material in a microwave or in electromagnetic field. But in order to remove the moisture from agricultural product such as cotton seed the bulk of product is to be handled in less time, also very less amount of moisture is to be removed i.e. about 7 to 8% only. Hence over 85 percent of industrial dryers are of convective type which uses hot air or direct combustion gases as the drying medium. So in this review we focus only on hot air convective dryer only. Drying is one of the most energy-intensive unit operation due to the high latent heat of vaporization and the un-effectiveness (in economic concern) of using hot air as the (most common) drying medium. So here we will focus on how to improve the thermal efficiency of cottonseed dryers, by studying the thermodynamics of the rotary drum cotton seed dryer, and then try to put forth the best efficient design for it.

For the enhancement of performance of the dryer it was tested with and without the insulation of surface area of the drum. To insulate the dryer's surface area the expanded polystyrene sheets was used, because of their low cost and good heat insulation properties. But the use of expanded polystyrene sheets is not preferable for the large industrial dryer, because they are very delicate to use and can get damaged easily. But instead of expanded polystyrene, extruded polystyrene sheets or blankets can be used. Extruded polystyrene has nearly same properties that of the expanded polystyrene.

What is Hot Air Dryer: Dryer is device which contains mainly of heat source, air blower, hot air conveying duct, and drying chamber. The drying chamber is our rotating drum in which the feedstock is poured and then hot air is blown over it. Due to the revolving motion of the drum the seed get suspended in the hot air continuously and hence lose their moisture to the hot air. Here in order to heat the air, the heat is transferred from the heat source to the atmospheric air, then this heated air is convey to the rotating drum with the help of duct. In this way the whole operation takes place. The moisture removal rate can be controlled by using electrical resistance type meters, dielectric moisture meters, modern portable moisture balances or by weight measurement. This whole system is shown in the following schematic diagram.

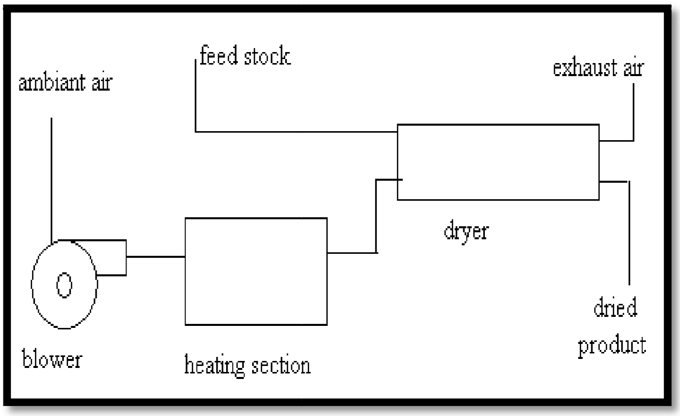

Figure-1
Basic view of cotton seed dryer

Methodology

The experimental setup used for this research consists of a blower, a variable frequency drive, a motor, gear box, rotary drum with flights, chain drive, nicrome wire coils, heating chamber, thermocouples (k-type), and dimmer stat to control temperature. Figure-2 shows the schematic diagram of the experimental setup.

Working procedure: The atmospheric air was supplied to the heating chamber with the help of blower. While doing this the mass flow rate of the air was set to a desired value by measuring the flow with orifice meter. Then the air is heated with electric heating up to a desired value. Once the required temperature is reached then the wet feed product *i.e.* cottonseeds was poured in the dryer, in a batch of 10kg for each time. Then seeds were rotated in the dryer for a period of 10 min. after that the heat supply to the air was cutoff and the entire mass of cottonseeds was taken out of the dryer. The weighing of these dry seeds was done in order to find the amount of moisture removed from them. This method of calculating the moisture removal is known as weight loss method.

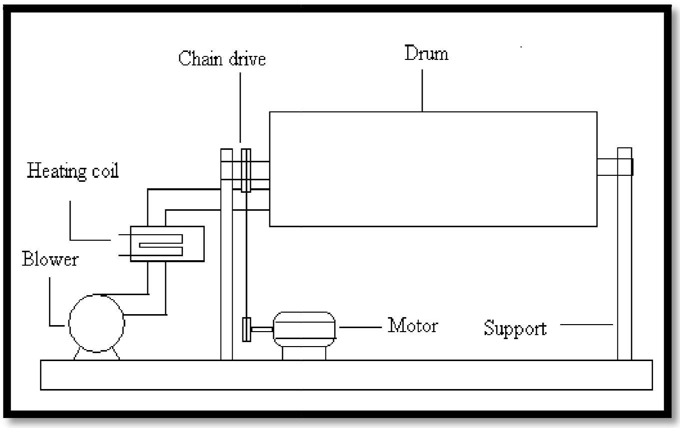

Figure-2
Schematic view of experimental setup

The above was followed without the insulation of the drum's horizontal surface and was repeated for different mass flow rate and heating temperature of air. The same procedure was carried out with the insulation of the drum's horizontal surface to evaluate the effect of heat insulation on dryer's performance. Following table shows the various fixed and variable parameters set for the experimentation.

Table-1
Setup specifications

Items	Specifications
Blower	1 HP, 460Volts
Drive motor	1 HP, 460Volts
Gear box	Reduction ratio of 1 : 40
Heating coil	1500 watt each
Drum	Dia. = 60cm, Length = 150cm
Flights	Length 140cm, width 6cm from drum wall and 3cm at 125° onwards
Thermocouple	K-Type (probe thermocouple)
Orifice meter	Diameter = 1.4cm, cd = 0.6
Pipe	Diameter = 3.6cm
Dimmerstat	0-4Amps
Expanded polystyrene	Thermal conductivity = 0.033W/m°K, thickness = 10mm

Table-2
Fixed / Variable parameters

Parameters	Fixed / Variable
Seeds quantity	10kg for each time
Operation time	10 minutes
Mass flow rate of air	0.00563kg/s, 0.0064kg/s, 0.00709kg/sec
Temperature	100°C, 110°C, 120°C
Drum rpm	20 rpm
Insulation thickness	10mm

For the above experimental procedure the rotation of the drum was selected from various references as it is suitable for (two segmented flights) the proper distribution of the seeds within the dryer. This rpm was constant throughout the all experimental readings.

Expression used for the calculation of heat transferred to the ambient air for drying;

$Q = m_a \times c_p \times (T_{out} - T_{amb})$

Where, Q = heat transferred to the air in heating chamber, m_a = mass flow rate of air, c_p = specific heat of air (1.005 kj/kg°k), T_{out} = temperature of air at the outlet of heating chamber, T_{amb} = temperature of ambient air.

Observations: A] Without insulating the drum's horizontal surface.

Table-3
Observation table for mass flow rate of air = 0.00563kg/s and 10 min of drying time

Sr. no.	Temperature (°C)	Heat supplied to ambient air (kw)	Mass of seeds (kg)	Moisture evaporated (kg)	Percentage of moisture evaporated by weight %
1	100	0.40739	10	0.293	2.93
2	110	0.464	10	0.308	3.08
3	120	0.5205	10	0.318	3.18

Table-4
Observation table for mass flow rate of air = 0.0064kg/s and 10 min of drying time

Sr. no.	Temperature (°C)	Heat supplied to ambient air (kw)	Mass of seeds (kg)	Moisture evaporated (kg)	Percentage of moisture evaporated by weight %
1	100	0.463104	10	0.306	3.06
2	110	0.5274	10	0.319	3.19
3	120	0.592	10	0.379	3.79

Table-5
Observation table for mass flow rate of air = 0.00709kg/s and 10 min of drying time

Sr. no.	Temperature (°C)	Heat supplied to ambient air (kw)	Mass of seeds (kg)	Moisture evaporated (kg)	Percentage of moisture evaporated by weight %
1	100	0.51303	10	0.328	3.28
2	110	0.5843	10	0.366	3.66
3	120	0.65554	10	0.438	4.38

B] With the insulation of the drum's horizontal surface.

Table-6
Observation table for mass flow rate of air = 0.00563kg/s and 10 min of drying time.

Sr. no.	Temperature (°C)	Heat supplied to ambient air (kw)	Mass of seeds (kg)	Moisture evaporated (kg)	Percentage of moisture evaporated by weight %
1	100	0.40739	10	0.306	3.06
2	110	0.464	10	0.320	3.2
3	120	0.5205	10	0.340	3.4

Table-7
Observation table for mass flow rate of air = 0.0064kg/s and 10 min of drying time

Sr. no.	Temperature (°C)	Heat supplied to ambient air (kw)	Mass of seeds (kg)	Moisture evaporated (kg)	Percentage of moisture evaporated by weight %
1	100	0.463104	10	0.323	3.23
2	110	0.5274	10	0.348	3.48
3	120	0.592	10	0.408	4.08

Table-8
Observation table for mass flow rate of air = 0.00709kg/s and 10 min of drying time

Sr. no.	Temperature (°C)	Heat supplied to ambient air (kw)	Mass of seeds (kg)	Moisture evaporated (kg)	Percentage of moisture evaporated by weight %
1	100	0.51303	10	0.374	3.74
2	110	0.5843	10	0.412	4.12
3	120	0.65554	10	0.478	4.78

Results and Discussion

The results of the experiment shows that the process of cotton seed drying was greatly influenced by the drying temperature, drying air mass flow rate, and exposure time. It was clear that the moisture extraction value goes on increasing remarkably, with increase in the temperature and mass flow rate of the drying air. Also performance of the dryer increases with the application of the insulating material (expanded polystyrene) on the horizontal surface of the drum. Following graphs clears the results of this research work.

Figure-3 Describes that the quantity of moisture extracted from the cotton seeds was directly proportional to the mass flow rate and drying temperature. Also it shows that the best performance was given at the peak flow rate and temperature. The amount of moisture extracted in same period of time was greater for the highest temperature and mass flow rate.

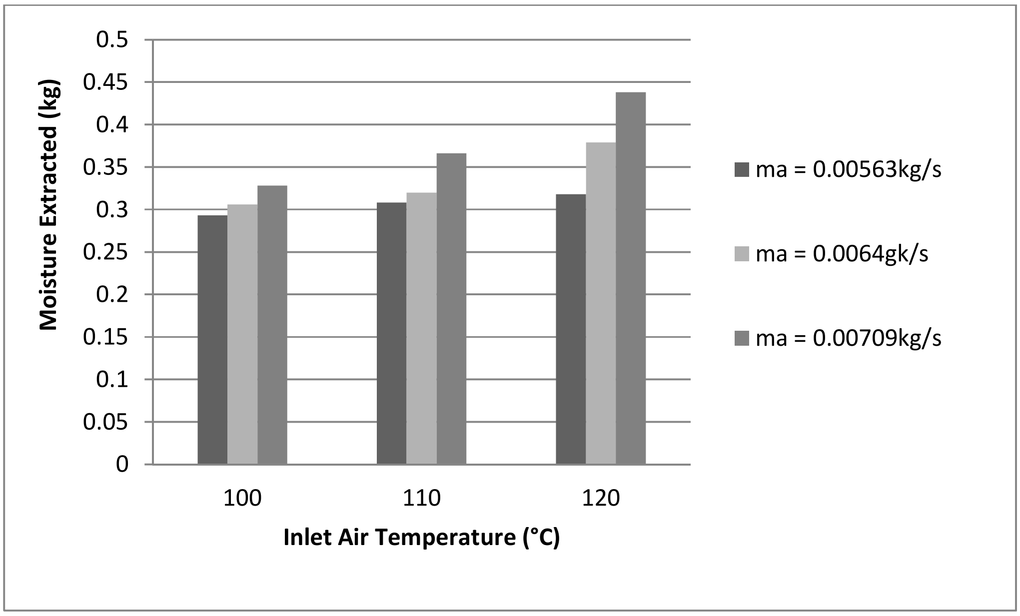

Figure-3
Comparison of moisture extracted at different flow rate and temperature without the insulation of the dryer

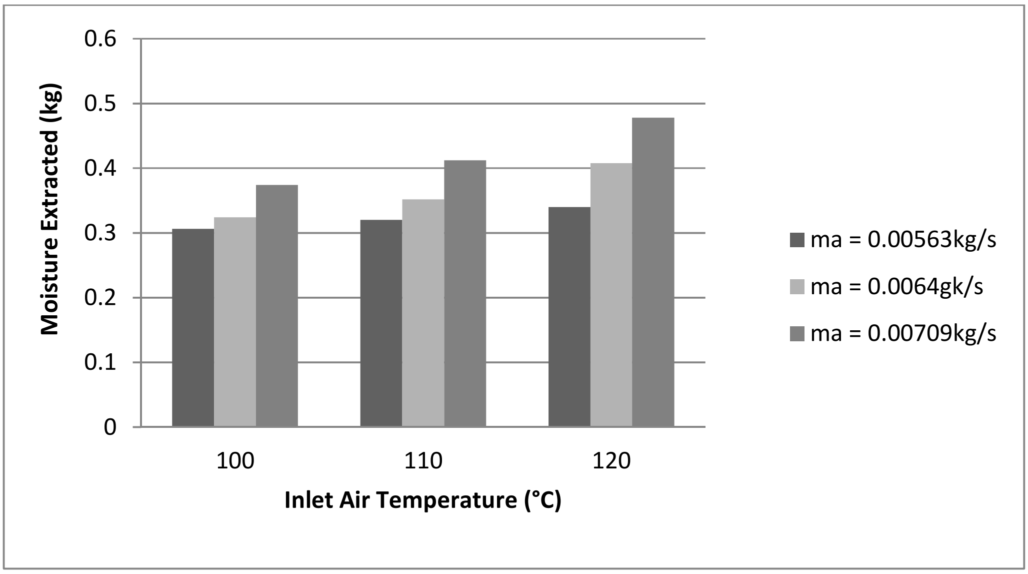

Figure-4
Comparison of moisture extracted at different flow rate and temperature with the insulation of the dryer

Figure-4 Describes that when the insulation was given to the drum surface there seems to be a great improvement in the dryer performance for the same operating condition as that for the previous condition of no insulation on surface of dryer. Here also the best performance was observed at the peak values of temperature and flow rate.

Conclusions

From the above observations and results it was concluded that the required amount of moisture to be extracted from the cotton seeds will be control by controlling the mass flow rate and temperature of the drying / heating air. With the help of these parameters the drying process will be calibrated for specific amount of moisture extraction according to the need.

Also with the help of insulation of the drum surface more moisture was extracted in same exposure period. This will evidently increase the efficiency of the dryer. It was note worthy that only insulation of drum's horizontal surface shows such improvement, so large improvement will be observed with the all heat exchanging surfaces such as two cross sectional sides of drum, heating chamber, hot air conveying pipe/duct *etc.*

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