Research on the Combined Microwave-Hot Air Drying of Seed Cotton

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Abstract. Moisture content of seed cotton has an important effect on cotton processing and the quality of its final products quality. At present, cotton processing enterprises dry seed cotton with hot air drying, which is difficult to control and results in high energy consumption and serious pollution. Experiments of combined microwave-hot air drying of seed cotton were designed and the feasibility of it was proved. A three-factor and three-level orthogonal regression rotation experiment of seed cotton drying was designed to study the influences of hot-air temperature, initial moisture content of seed cotton and power density, and order of the three factors- initial moisture content of seed cotton > power density > hot air temperature was concluded. A control model of seed cotton drying was established to find out a new process route for seed cotton drying and provide a theoretical basis for the implementation of combined microwave-hot air drying of seed cotton.

1. Introduction

Initial moisture content of seed cotton is the mass ratio of water and pure dry seed cotton. Previous experience and research results showed that lint quality was the best when initial moisture content of seed cotton was between 6.5% and 8.5%[1]. The moisture content of seed cotton collected by ginneries is commonly much higher, so it is necessary to set up a drying process in the pretreatment of seed cotton. This paper designed experiments on combined microwave-hot air drying and estabilshed the control model of combined microwave-hot air drying of seed cotton.

2. Analyses of the Principles and Processes of Existing Seed Cotton Drying

Domestic ginneries use hot air to dry seed cotton with equipments. The air blown by the blower is heated into hot air by heat exchanger, and then be mixed up with seed cotton in the cotton pipe (the highest temperature is about 120℃ after mixing) to be dried by drying tower. The seed cotton finally goes out of the drying tower from seed cotton outlet and hot air is discharged to the atmosphere. Hot steam, which is the heat source of this drying equipment, is mostly provided by coal fired boiler.The current drying process has the following disadvantages:

1) It is of high energy consumption and low energy utilization rate. 2) The process is complicated. 3) It is prone to damage cotton fibers if drying temperature is too high. 4) Temperature adjustment is slow. 5) The pollution is serious.

Microwave drying is to achieve the drying purpose by quickly inducing inside material produce thermal effect with high frequency alternating electric field, and the material is heated from inside to outside. Compared with traditional hot air drying, microwave drying has advantages of higher drying speed, less energy loss, lower temperature of material, smaller thermal inertia, energy conservation and environmental protection etc[2]. And microwave drying also has disadvantages.The internal water of material transfers to the surface and it causes condensate phenomenon when there is too much water in the material, because microwave drying is quick and it is dried from inside to outside.

Thus the material is very dry inside with a damp surface.The principle of hot air drying is to heat the surface of material with hot air, and then transfer heat to the internal of material by heat conduction, so it is dried from outside to inside. Such characteristic is complementary to that of microwave drying. Thus this paper puts forward a combined microwave-hot air drying as the basis, supplemented by hot air drying. This new method gives full play to the advantages of microwave drying and solves the condensate phenomenon caused by microwave drying by supplementary hot air drying.

3. Experiment design

3.1 Materials and methods.

This experiment used the seed cotton picked up by machine in Xinjiang as material. A certain amount of seed cotton samples were taken to be moderately humidified with moisture content kept stable at 7%, 11%, and 15% (7% was the midpoint of the interval of 6.5%~8.5%; 11% was chosen because about 4% water is removed after one drying; and 15% was the upper limit of moisture content when ginners collected seed cotton), and then be put respectively into polythene bags and sealed.

The Second Cotton Ginning Factory of Xinjiang 149 Corps was chosen as test site, and drying system, which was produced by Shangdong Swan Cotton Industrial Machinery Stock Co., Ltd including MG-10 drying tower (output for 10000 kg/h), 4-72-8c heat blower (power for 22 kw) and steam - steam heat exchanger. Y412B-raw cotton moisture meter, produced by Taicang Electronic Instrument Co., Ltd, was used as the moisture detection equipment.

MG-10 drying tower is of 24 layer partition type, using hot air drying method. To realize combined microwave-hot air drying, it needs to be reformed as follows: 200 (obtained through calculation of maximum yield-10 tons of drying tower and power of microwave generator) microwave generators of the 2M167B-M11 type, produced by Panasonic company, were set up evenly on 4 inner surfaces of the drying tower.

Research showed that hot air velocity, hot air temperature, initial moisture content of seed cotton and microwave power density were main factors affecting combined microwave-hot air drying, however, air was the impetus to drive seed cotton moving forward in real production, so that air velocity needs to keep constant(usually 20m/s). In order to obtain the control model of combined microwave-hot air drying of seed cotton, a three-factor and three-level orthogonal regression rotation experiment of seed cotton drying was designed [3-6]. The setting of factors and levels was shown in Table 1.

Table 1. Setting of Factors and Levels

Level	Factor		
	Hot air temperature(℃)	Initial moisture content(%)	Power density(W/g)
+1.682	73.64	17.05	15.78
+1	60	15	13
0	40	12	9
-1	20	9	5
-1.682	6.36	6.95	2.27

3.2 Results and discussion.

Results of experiments are shown in Table 2.

Table 2. Design of Qudratic Orthogonalratation Experiment of Three Factors and Three Levels

No.	Hot air temp-erature (℃)	Initial moisture content (%)	Power densit y (W/g)	Final moisture content (%)	No.	Hot air temp-erature (℃)	Initial moisture content (%)	Power densit y (W/g)	Final moisture content (%)
1	20.00	9.00	5.00	7.54	13	40.00	12.00	2.27	10.98
2	20.00	9.00	13.00	3.10	14	40.00	12.00	15.78	3.02
3	60.00	9.00	5.00	6.34	15	40.00	12.00	9.00	7.35
4	60.00	9.00	13.00	0.50	16	40.00	12.00	9.00	7.52
5	20.00	15.00	5.00	12.89	17	40.00	12.00	9.00	7.13
6	20.00	15.00	13.00	8.50	18	40.00	12.00	9.00	7.26
7	60.00	15.00	5.00	11.15	19	40.00	12.00	9.00	7.33
8	60.00	15.00	13.00	5.00	20	40.00	12.00	9.00	7.55
9	40.00	6.95	9.00	2.77	21	40.00	12.00	9.00	7.48
10	40.00	17.05	9.00	10.45	22	40.00	12.00	9.00	7.24
11	6.36	12.00	9.00	9.00	23	40.00	12.00	9.00	7.18
12	73.64	12.00	9.00	5.02					

Results of the experiments were fit with ternary quadratic polynomial, and a regression equation was obtained as (1):

$$y = 0.2431x_1 + 1.3148x_2 - 0.2978x_3 - 0.1239x_1^2 - 0.5499x_2^2 - 0.1339x_3^2 - 0.2208x_1x_2 - 0.3319x_1x_3 - 0.0409x_2x_3 \quad (1)$$

where x_1 was hot air temperature; x_2 was initial moisture content; x_3 was power density; y was final moisture content. For (1), coefficient of determination R^2 equaled to 0.9947, and Table 3 was obtained after the variance analysis of (1).

Table 3. Result of Variance Analysis

Source of variation	quadratic sum	Degrees of freedom	Mean square	Ratio of F
Regression	186.30	9	20.70	F =463.66
Remainder	0.58	13	0.58	
Lack of fit	0.18	5	0.18	F_{Lf} =0.73
Error	0.40	8	0.12	
Sum	186.88	22		

It could be known that $F_{0.05}(5,8) = 3.69$， $F_{0.05}(9,13) = 2.71$ from the F table, and $F_{Lf} < F_{0.05}(5,8)$ indicated that the equation fit very well; $F > F_{0.05}(9,13)$ meant that (1) was significant.The regression coefficients were tested in significance, and results were shown in Table 4.

Table 4. Significance Analysis of Regression Coefficient

Coefficient	value of P	Coefficient	value of P
x_1	0.045791	x_3^2	0.063883
x_2	0.000001	x_1x_2	0.031524
x_3	0.019726	x_1x_3	0.000147
x_1^2	0.057184	x_2x_3	0.670672
x_2^2	0.000337		

From Table 4, it could be known that the order of factors affecting final moisture content of seed cotton was: initial moisture content(x_2) > power density(x_3) > hot air temperature(x_1). After eliminating insignificant items, formula (1) could be rewritten as:

$$y = 0.2431x_1 + 1.3148x_2 - 0.2978x_3 - 0.5499x_2^2 - 0.2208x_1x_2 - 0.0409x_2x_3 \quad (2)$$

In order to validate the accuracy of the established model, it was necessary to do a verification experiment. Drying system run 600 s, once every 5 s inspection 1 seed cotton initial moisture regain, computing fitted value is compared with measured values, and results are shown in Fig.1.

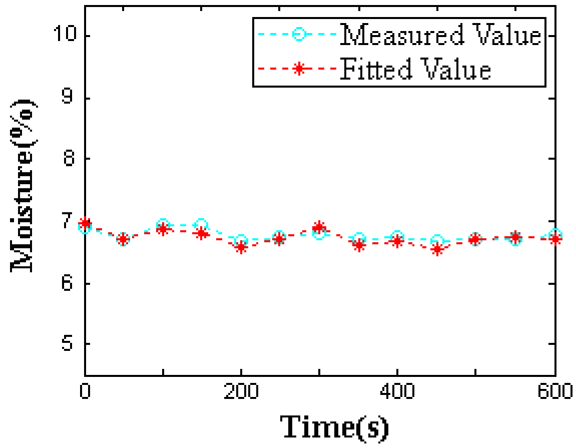

Fig. 1 Validation curve of the model

4. Conclusion

The hot air drying used by cotton factories caused high energy consumption and inaccurate control, so on the basis of the principle of microwave drying, this paper designed experiments on hot air drying and combined microwave-hot air drying and found that combined microwave-hot air drying had better effects. The orthogonal regression rotation experiment of three factors and three levels of seed cotton drying was designed, and the order of factors influencing drying effects was: initial moisture content(x_2) > power density(x_3) > hot air temperature(x_1), and control model of combined microwave-hot air drying of seed cotton was established, providing a theoretical basis for the improvement of seed cotton drying process.

Summary

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