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Electrical technology of moisture content reduction of industrial-grade cotton seeds

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Abstract. The electric-contact heating method is proposed to be applied to reduce the moisture content of the industrial-grade cotton seeds to meet the relevant standard requirements. The rationale for safe heating conditions has been provided. The effect of different factors on the efficiency of the preliminary drying of seeds has been studied. Theoretical and graphic laws of the specific energy consumption change depending on different parameters have been defined. The obtained results prove the high efficiency of the proposed method: specific energy consumption decrease by 2.8 – 3.8 times against the existing technology.

1. Introduction

The technology of primary processing of seed cotton involves the following major operations: drying, ginning (separation of cotton from seeds), linting (separation of cotton fluffs from seeds), compressing, and packing to separate bales. The grade 1 and 2 cotton seeds separated from fluffs shall be used as seed material. The grade 3 and 4 cotton seeds separated from fluffs shall be stored and periodically delivered to oil mills for the production of oil, seed shell, and oil cake. At that, the storage of industrial-grade cotton is a big problem, as its moisture content comes to around 16-18%. This causes annual losses of 12-15% of stored products. [1-6]. The most commonly used method of storage of such seeds consists of the application of an active ventilation method.

The use of hot-air blowing is distinct in high specific energy consumption, about 6-8 MJ per kilogram of evaporated moisture [7-10]. The use of infrared radiation shall require the delivery of thin-layer seeds, which certainly impacts the process unit's capacity. It becomes necessary to develop an efficient, low energy-consuming electrical process facility that will allow reducing the total moisture content of industrial-grade cotton seeds from 16-18% to 10-13% [11-15]. At that, according to production requirements, the existing primary seed cotton processing facilities should not undergo considerable structural and technological changes [16-25].

The purpose of this research is to study the effect of the selected design parameters and operating conditions of the facility upon the energy consumption and quality of pre-drying of industrial-grade cotton seeds.

Research objectives: 1) development, making and tuning up of laboratory facility; 2) provision of electrical and fire safety conditions; 3) study of the effect of seed movement rate on specific energy consumption at different values of the temperature of heating surface and air velocity

2. Methods

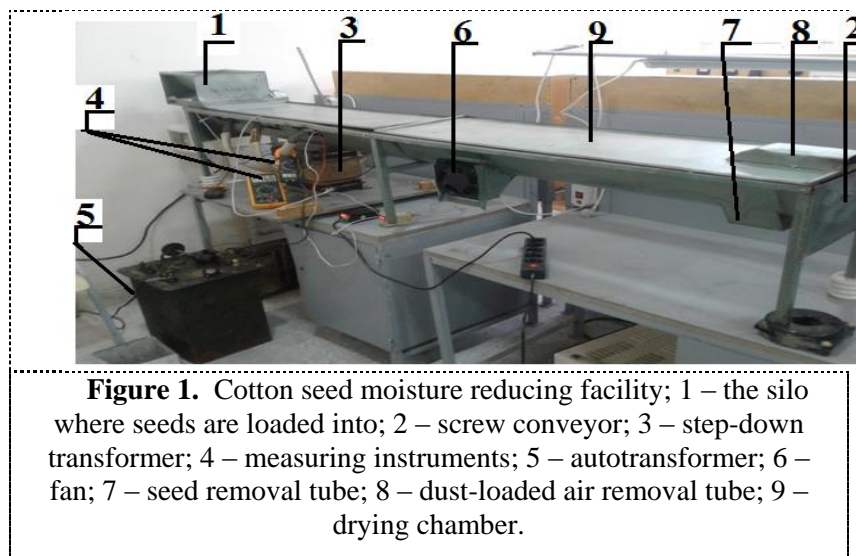
To assess the energy efficiency of the processing modes, values of the specific energy consumption per kilogram of evaporated moisture q (MJ/kg) have been adopted; they represent the ratio of the energy consumed for drying Q (MJ) to the weight of evaporated moisture M (MJ/kg). This criterion allows comparing different drying methods against each other with sufficient flexibility. Seed moisture content shall be determined by using a special device "Sifat". The energy consumption shall be determined from readouts of measuring instruments taking into account the heater efficiency factor



and the facility efficiency factor. Experiments were conducted with three replications at the confidence level $\alpha = 0.95$. The experiment results were assessed by statistical methods

3. Results and discussion

The facility operates as follows. Cotton seeds shall be dried during the movement of the seeds on a screw conveyor. The seeds loaded into storage silo 1 through feeding screw 2 and get to the sheet placed in the drying chamber that is heated by means of step-down transformer 3. When the seeds are heated, moisture shall exude from them, which shall be removed by cold-air blowing by using fan 6. Blowing of heated seeds by the cold air of the fan shall accelerate moisture exudation and removal. Dust-loaded air shall be removed through tube 8. An air gate shall be used to keep the air in the fan in normal condition. The seeds with moisture content decreased to 10% shall be removed through tube 7.



The heating surface is located horizontally and has the cut-out cylinder shape, which provides good contact with the material being dehumidified. The electric heating element allows adjusting the heater surface temperature from 20 °C to 200 °C. The screw conveyor rotation speed can be adjusted from 1 to 10 rpm; seed movement speed is from 0.0083 m/s to 0.0166 m/s. The maximum voltage on the secondary side of the heating transformer is 0.5 V; at that, the secondary winding current of the transformer feeding the heater comes to 360 A.

The screw conveyor drive motor power is 0.16 kW. The fan motor power is 0.26 kW. One-time moisture removal comes to 5-6%. The facility capacity is 0.12 ton/hour. The maximum seed heating temperature shall not be higher than 70 °C. The required electric and fire safety conditions have been provided. The voltage on the secondary winding of the transformer shall not exceed 0.5 V. The electric-contact heating chamber top shall be covered with a special cover. The ultimate temperature of the heater shall not be higher than 200 °C.

The studies conducted with the aim to define the relation between the specific energy consumption for moisture evaporation with seed movement rate under different temperatures of the heating surface and air velocity have shown that this relation between well approximated by the following equation:

$$y = a_0 + a_1 + a_2 x^2 \quad (1)$$

The coefficients of this equation obtained when substituting correlation ratios in the equation are given in Table 1.

Table 1. Coefficients of the equation of the relation between the specific energy consumption for moisture evaporation with seed movement rate under different temperatures of the heating surface and air velocity.

Average heating surface temperature, °C	Air velocity, m/s	Equation coefficients			Correlation ratio R
		a_0	a_1	a_2	
120	3.5	4.6405	-493.32	15910	0.983
	3	3.9546	-350.87	10091	0.9604
	2.5	4.5171	-514.36	18103	0.9129
130	3.5	4.7861	-450.36	13822	0.92
	3	4.7021	-510.01	18820	0.8732
	2.5	5.4328	-640.44	23778	0.8485
140	3.5	5.3788	-577.18	19310	0.8671
	3	3.3584	-258.98	7166.9	0.8526
	2.5	3.9883	-398.9	13478	0.8574
150	3.5	5.4943	-600.3	20511	0.8659
	3	4.171	-392.55	12623	0.8413
	2.5	6.713	-847.38	30653	0.9609

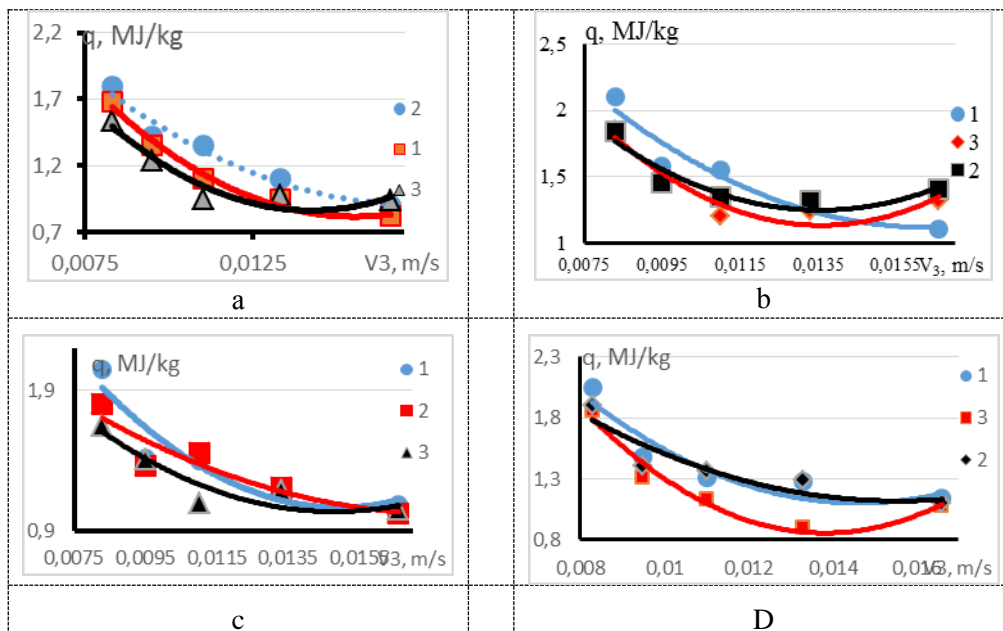


Figure 2. Relation between the specific energy consumption for moisture evaporation with seed movement rate under different temperatures of the heating surface and air velocity; a is heating surface temperature 120 °C; b is heating surface temperature 130 °C; c is heating surface temperature 140 °C; d is heating surface temperature 150 °C; 1 is $V_{air} = 3.5$ m/s; 2 is $V_{air} = 3$ m/s; 3 is $V_{air} = 2.5$ m/s;

Note: specific energy consumption is given in MJ/kg for comparison with the existing hot-air blowing technology.

Analysis of the curves shown in Figure 1 shows that specific energy consumption q for evaporation of moisture from cotton seeds decreases with the rise in their movement rate down to a certain value, i.e. (0.85 – 1.25) MJ/kg; then it starts increasing. At that, a more intense drop of q takes place at higher air velocities; while at lower air velocity, this intensity lowers.

4. Conclusions

1. A laboratory facility that allows reducing the moisture content of industrial-grade cotton seeds from 16-18% to standard 10-13% has been developed and tested. It has been found out that in this case specific energy consumption decreases by 2.8-3.8 times in comparison with the existing hot-air blowing technology.

2. Electric safety conditions shall be provided due to the lowered voltage of the heating transformer (no more than 0.5 V) and reliable grounding of the facility body. Fire safety shall be provided by setting the maximum heater temperature at 200 °C.

3. The regression equation describing the relation between the specific energy consumption for moisture evaporation with seed movement rate in the facility under different temperatures of the heating surface and air velocity is given. The regression equation coefficients have been determined by experiments as well as characteristic curves have been plotted.

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