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Study of Effect of Speed and Temperature of the Drying Agent in the Feeder-Loosened of New Design on the Quality of Fiber

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ABSTRACT

It has been scientifically proved that over dried cotton fiber loses valuable natural properties: it becomes fragile, brittle, physical-mechanical, spinning and performance properties of products made from this fiber are deteriorated, and the content of defects and foul of the fiber are increased. Preparation of the material mixture and the control of the temperature and feed rate of the drying agent at the inlet of the drying device is important to obtain a quality product. Results of scientific research work on analysis of the drying process of raw cotton are presented, and method for the analytical calculation of thermal-physical indicators and the efficiency of its thermal conductivity is developed. Dependence of the drying parameters on the air rate is studied. Influence of these technological parameters on the intensity of moisture removal in raw materials and, as a consequence, shortening in duration of drying process was established. For example, the drying intensity in the initial period is 1.16 times higher than that in existing dryer (reference sample). Research aimed at improving the process of conductive drying of raw cotton was carried out in purpose to reduce the temperature effect on the natural quality indicators of cotton. According to the results of the research, laws of changes in the quality indicators of cotton and its components, as well as the process of mixing of the drying agent are revealed, the dependence of the rate regimes of the new device that positively affect the technological processes of treatment and quality indicators of raw cotton is received. The main purpose of this scientific work was to improve the design of the feeder of the drying unit for loosening cotton fiber, improving its quality and saving specific fuel consumption. In this purpose, it is necessary to conduct a study of the process of grinding lumps of raw cotton, the dynamics of their fusion with a drying agent and the prerequisites for creating a mixture. The results of the study (improving the spinning-technological properties of the fiber, reducing the foul of the webs from 161 to 157 pieces per 1 g, increasing the elongation from 5.6 to 6.4% ...) will be useful to employees of cotton-cleaning enterprises, scientists and researchers.

Key words: Raw Cotton, Fiber, Seeds, Drying, Artificial Drying, Heat Agent, Dryer, Spiral Drum, Temperature.

1. INTRODUCTION

At present, the main direction of development and improvement of drying equipment is to increase its productivity, as well as the combination of raw cotton drying and cleaning processes in one device. Such a solution has found application in drum-type dryers based on the convective drying method, which is widely used in drying-cleaning and cleaning workshops of cotton-cleaning enterprises.

In recent years, new types of cotton dryers of type 2SB-10 (Fig. 1) have been developed and dryers of the SBO brand (Fig. 2) operating on natural gas (TG-1.5 brand) and liquid fuel (TG-1.5) have been improved. Drying, cleaning and cleaning workshops now equipping with them.

These dryers mainly meet modern industrial needs in terms of their performance criteria. At present, 2SB-10 and SBO drum dryers are widely used in the cotton cleaning industry.

Drum dryers 2SB-10 include: feeder, drum, exhaust pipe. Drying drum with the diameter of 3200 and length of 10000 mm is made of two-millimeter sheet steel. Inside there are twelve longitudinal blades mixing raw cotton and pushing it along the drum.

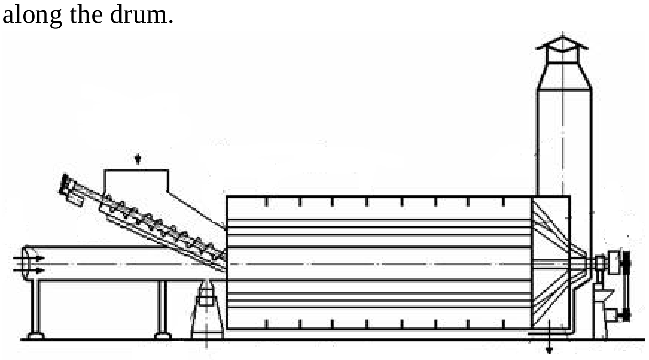


Figure 1: Technological scheme of the drying drum 2SB-10

The blades with the height of 500 mm high are fixed radially, and at drum speed of 10 rpm provide stable dryer operation when the drum is filled by 30.0%. Inside the drum at the distance of 3000 mm from its front wall there is a braking grating with length of 6000 mm, which consists of three rods and is attached by means of crossbars to drum shell parallel to its longitudinal axis. Because of grating, the time of raw cotton being in the drum under the influence of drying agents increased, which helps to shortening heat consumption for drying [1,2].

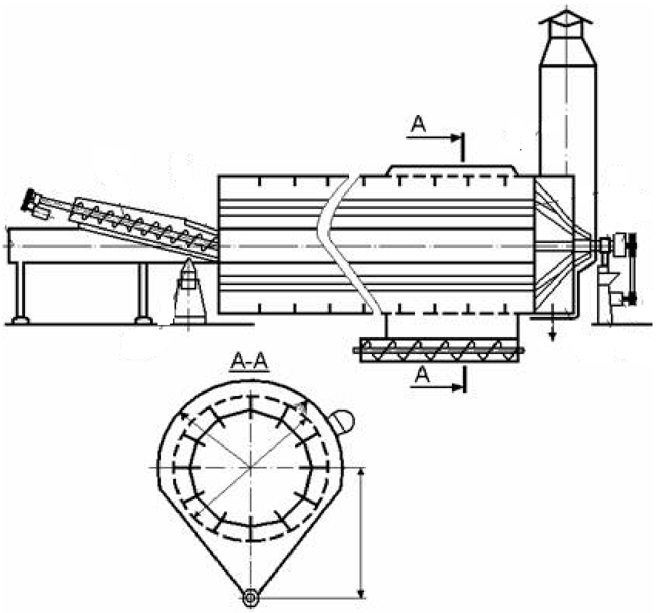


Figure 2: Technological scheme of the drying drum SBO

During consideration of existing dryers from the point of view of their efficiency, drying quality and fuel consumption, it can be noted that incoming process parameters have practically no effect on changes in the moisture and density of raw cotton in the batch being processed, the feed rate for drying and its physical condition when they function. This circumstance significantly reduces the efficiency and quality of products in the subsequent processing of raw cotton.

Production studies of the raw oil moisture state after dryers have shown that cotton is not uniform in volume within quite wide limits, which negatively affects the efficiency of cleaning machines. Therefore, at the current stage of development of cotton cleaning industry is relevant the question of finding ways to change the physical state (loosening, mixing and decompression of lumps), methods of leveling and preliminary heat on the drying of raw fruit, i.e. carrying out the process of preparation of raw cotton for drying ensuring increase of its efficiency, quality and economy. From the above it follows that in order to solve this problem, it is necessary to develop a dryer feeder device with a loosening and distributing member, to form a mixture of raw cotton and a drying agent flow, which provides more uniform drying in order to improve the quality of the produced fiber and more efficient fuel consumption [3,4].

2. MATERIALS AND METHODS

Based on the analysis of the stated requirements, a new design of the feeder-loosened for the drying drum (Fig. 3) with cone-shaped coolant was developed [5].

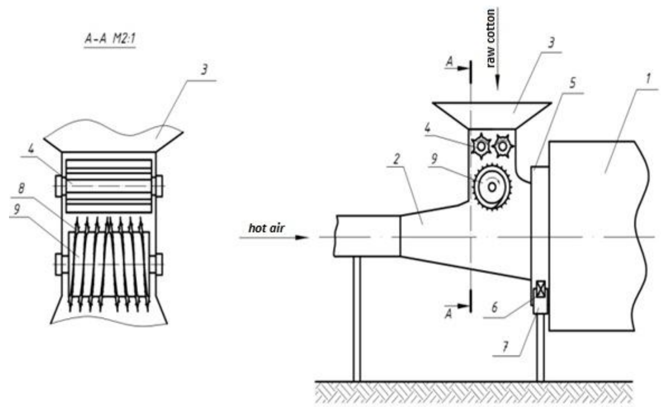


Figure 3: Scheme of feeder-loosened

Main point of the design is that the device for drying raw cotton containing a rotating drum 1 with drying cleaning sections having radial blades and an axial nozzle 2 for input drying agent and feeding raw cotton, is made cone-shaped, which ensures complete distribution of the heat flow inside drum and helps to reduce transit heat loss from the dryer. The device is installed in the front part of the drying drum in the upper part of the conical pipe, including two star-shaped feed rollers 4 and a rotating screw drum 9. Stakes with the height of 50 mm are installed along the length of blades 8 of the screw drum 9 for the effective loosening of the raw cotton and its uniform distribution in the area of the heat flux. Proposed design of feeding cotton into the dryer can significantly increase the intensity of influence of drying agent on cotton due to a sufficient degree of loosening. This will also significantly reduce heat loss. It is known that in the area where cotton falls into the drum, the effect of the drying agent is limited due to the uneven distribution of heat flow in the nozzle due to the inlet of the loading device, which prevents the flow of hot air. At the same time, due to the increase in the diameter of the outlet part of the nozzle, the zone of flow of hot air also increases, which allows the heat and mass transfer process to occur freely in the zone of falling of cotton into the drum in a loose state.

The outer journal of the drum is increased by 2.5 times in order to improve heat and mass transfer and reduce the load on the supports of the pads and rollers. The temperature of the internal devices of the dryer was measured using a KSP-4 potentiometer with flat chrome-copal thermocouples of the THK type. The moisture content of the raw cotton was determined in an SHSH oven. Modern research methods using effective techniques and instruments have been applied in order to study changes in fiber quality depending on the intensity of drying in drum dryers.

Results: As we know, there is a process of self-heating during storage of raw cotton of high humidity. Therefore, it is necessary to bring this parameter to the standard rate. It has been established that the fiber strength of low cotton varieties decreases from 2.5-2.9 to 0.3 Gauss at temperatures up to 550 °C. In constant rate of the drying agent (recommended 0.6-1.5 m/s), the moisture mainly evaporates from the surface of the material [6-9].

When applying a temperature of 120-160 °C to ensure the moisture conductivity of the material, it is necessary to improve its diffusion-osmotic capillary strength due to preliminary loosening and mixing of cotton with a drying agent. One of the important factors in increasing the efficiency of the process of moisture conduction of particles, constituting the cotton mass in the field of a moving air stream, is the density of the material.

For this purpose, the task to determine the patterns of movement of particles of cotton mass when mixed with a stream of drying agent and transporting to the dryer was set. Differential equations for the motion of particles of mass M falling out at a certain speed on the impact of the airflow were determined (Fig. 4). Taking into account that the force of resistance to the movement of particles is determined by the quadratic equation of Newton, we can write:

$$\mathrm{M}\frac{\partial^2 x}{\partial t^2} = -K_1\sqrt{\left(\frac{\partial x}{\partial t}\right)^2+\left(\frac{\partial y}{\partial t}\right)^2}\,\frac{\partial x}{\partial t} + K_1\left[\left(\frac{\partial x}{\partial t}\right)_0 - \upsilon\cos\alpha\right]^2 \quad (1)$$

$$\mathrm{M}\frac{\partial^2 y}{\partial t^2} = mg - K_1\sqrt{\left(\frac{\partial x}{\partial t}\right)^2+\left(\frac{\partial y}{\partial t}\right)^2}\,\frac{\partial y}{\partial t} \quad (2)$$

$\left(\frac{\partial x}{\partial t}\right)_0$ –speed of horizontal airflow transporting raw cotton to the dryer, m/s;

v – speed of particle in a stream, m/s;

a – angle formed by the vector of speed of particle with the axis OX;

K_1 – coefficient of resistance of particle motion in the air stream.

After conversion, this equation takes the following form:

$$x = \frac{1}{2}\left(\frac{\partial x}{\partial t}\right)_0 t + \frac{1}{2K\left(\frac{\partial x}{\partial t}\right)_0}\left[\frac{1}{2}\left(\frac{\partial x}{\partial t}\right)_0 - (U_x)_0\right] * \left[e^{-2K\left(\frac{\partial x}{\partial t}\right)_0 t} - 1\right] \quad (3)$$

In order to specify the task and taking the form of particles in the form of a sphere, the value of K1 is determined [10].After converting equations (1) and (2), if necessary, the loosening effect of the installation can be determined by formula (4).

$$\mathrm{E}_P = \frac{\mathrm{N}_u - \mathrm{N}_1}{\mathrm{N}_u - 1}\cdot 100 \quad (4)$$

Where E_p– loosening effect of installation;

N_u– weighted average number of feathers in raw cotton lumps;

N_1 – the same, but after loosening.

Series of experiments was carried out in order to determine the base area of the mass of raw cotton, the results of which are shown in the Fig. 4. In some works [11], the drying mode with heated air is characterized by the moisture content of air W, its movement speed V and temperature T. However, studies have shown that the formation of a mixture of material with a flow of a drying agent has a significant effect on the drying intensity. To determine the drying intensity, raw cotton of the Bukhara-6 variety with initial moisture content of 14.0% was selected, and curves of its drying were obtained. In order to determine the effect of mixture formation on the drying intensity, experiments were performed at air speed of V = 1.0; 1.2; 1.5 m/s at the temperature of 150 °C

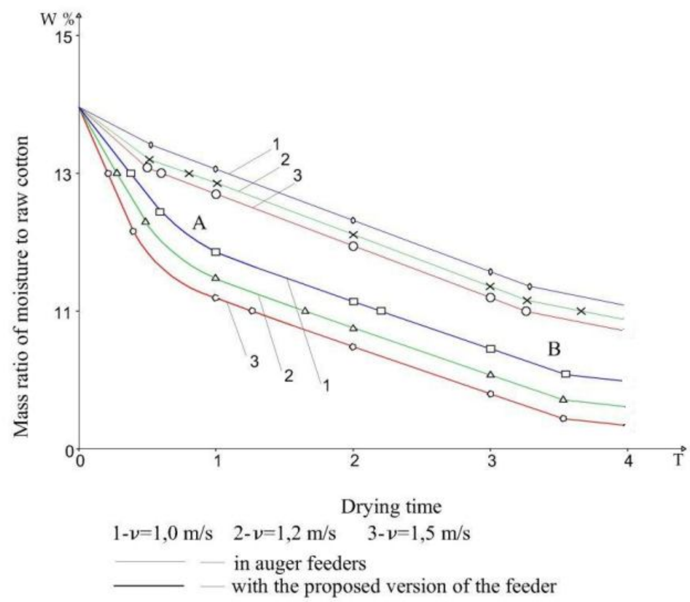


Figure 4: Influence of relative air speed on the moisture content of the material

As can be seen from the data of Fig.4.the increase in air speed increases the drying intensity in the first existing variant, and has a curve relationship in the initial period. This means that the drying intensity is lower, and more time is required to achieve a conditioned moisture content of the feedstock. At the same time, at the end it continues to decline. In the proposed version, the intensity of raw cotton moisture removal increases (A) at the beginning of the process, and then changes in the zone (AB), due to mixing of the drying agent with raw cotton and mixture of material is formed, due to which the intensity of moisture removal (drying) increases. Thus, the drying intensity during the first minutes is 1.16 times higher than in the present feeder version. During the mixing and loosening period of the raw cotton, moisture is removed relatively easily, and this process is slowed down from the moment of air supply. This is because at the beginning of drying the portion of moisture on the fiber surface and the seed peel prior to 25.0% is evaporated (Fig. 5). Then the external diffusion zone is started, in which the remaining part of moisture of fiber and seed peel is evaporated to 22.0%, and finally, in the internal diffusion zone (end of drying process) the strong-bound moisture from the seed core is evaporated. Therefore, the zone of internal diffusion over the drying time takes a longer interval.

The experimentally derived regression equation for the weighted average number of feathers in lumps of raw cotton after installation has the following form:

$$y_1 = 0.027Q + 0.031v - 2.54 \quad (5)$$

$$y_2 = -0.02Q + 0.61n + 0.65v - 5.79 \quad (6)$$

Where, y_1 – number of distributed feathers in the loosening zone of the screw drum, pcs;

y_2 – Base area of raw cotton heap after installation, m^2;

Q – Productivity on raw cotton, t/h;

n – Rotational speed of loosened-distributor, s^{-1};

v – Speed of air in channel, m/s.

3. RESULTS AND DISCUSSION

Regression coefficients of the equations were checked for significance by the Student criterion, and the adequacy was evaluated by the Fisher criterion. From the obtained mathematical models, it can be seen that all input parameters contribute to the growth of output parameters y_1, y_2.

Evaluation of the quality of the fiber after the process (drying, cleaning, ginning) for all indicators was carried out in the laboratory of the Peshku cotton-cleaning plant in the Bukhara region and in testing laboratory of "Sifat" association. Experiments were carried out with raw cotton of Bukhara-6 variety. Content of the mass fraction of defects and trash of fiber was determined by manual analysis of fractions according to the standard method [12-15]. The results of experimental research on existing and new installation are shown in Tables 1 and 2

Table 1: Content of defects and trash in the fiber during operation of dryer with screw feeder

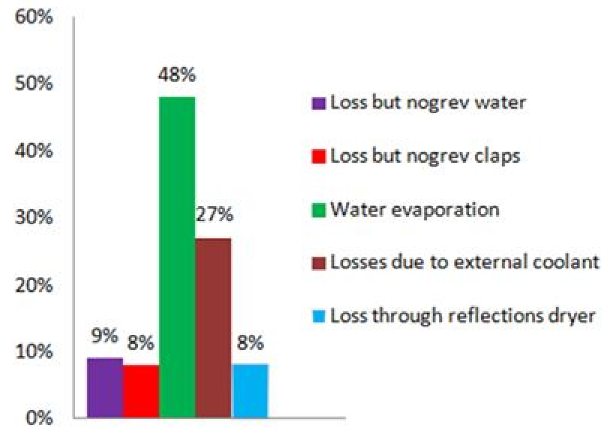
Indicators	Value of the indicators (%) in repeated experiments					Average value
	1	2	3	4	5	
Large latters	0.75	0.70	0.61	0.51	0.77	0.66
Small latters	0.4	0.55	0.52	0.51	0.40	0.47
Broken seeds + peel with fiber	1.24	1.30	1.29	1.54	1.25	1.32
Cotton gin mote	0.46	0.58	0.69	0.62	0.57	0.58
The content of defects and trash	3.05	3.120	3.19	3.02	3.0	3.07

Table 2: content of defects and trash in the fiber during operation of a dryer with feeder with loosening-distributing organ

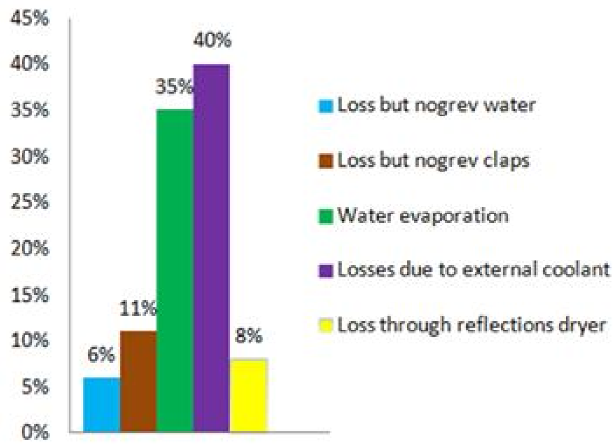
Indicators	Value of the indicators (%) in repeated experiments					Average value
	1	2	3	4	5	
Large latters	0.59	0.319	0.46	0.44	0.46	0.45
Small latters	0.43	0.31	0.39	0.3	0.31	0.34
Broken seeds + peel with fiber	1.25	1.31	1.35	1.61	1.20	1.34
Cotton gin mote	0.49	0.54	0.41	0.33	0.31	0.41
The content of defects and trash	2.66	2.78	2.54	2.71	2.79	2.69

At present, drying drum 2SB-10 mainly used in cotton-cleaning plants of Uzbekistan [16-19].To improve moisture removal and reduce fuel consumption, the inlet section of the pipe is selected so that the agent speed is not more than 1.6 m/s, which eliminates the release of some raw cotton feather through the dryer drum. In the fall zone, the loosened cotton is washed additionally with hot drying agent and is heated intensively. The amount of heat transferred to the material in the drop zone increases due to the radius of the airflow, and amounts to 87.0% of the total heat flow, and heat transfer from the surface of the material occurs more intensively. It is known that the efficiency of drying unit is equal to the ratio of heat amount spent on evaporation of 1.0 kg of moisture from cotton to the total amount of heat consumed (7)

$$\eta = \frac{q_1}{\sum q} \cdot 100\ \% \quad (7)$$



a)



b)

Figure 5: Heat consumption: a – existing option, b –proposed option

The figure 5 shows diagram of heat consumption at temperature of the coolant flow 140 °C in the existing and proposed option [20]. Feeder with loosening organ provides more uniform drying of the raw cotton in the dryer and, due to this, better cleaning on the subsequent equipment. At the same time, the specific consumption of fuel for drying is also significantly reduced. Consequently, the economic effect is achieved by reducing the content of defects and trash in the fiber produced by the cotton mill and more economical use of fuel.

Operation of the feeder dryer 2SB-10, which has screw auger with a screw diameter of 300 mm located at an angle of 30° to the horizon, with a rotation speed of 405 rpm has been studied. The new screw-drum-type dryer feeder with loosening organ is proposed, which allows providing more economical fuel consumption, improving the quality of the produced fiber due to formation of mixture of material with the drying agent flow and increasing the drying intensity. Differential equations for the movement of particles of mass M, falling out at a certain speed, on the effect of the air flow are compiled in order to establish the laws of movement of particles of the cotton mass at mixing with the flow of the drying agent and transporting them to the dryer. Using the obtained formula (4), if necessary, we can determine the loosening effect of the installation:

$$E_P = \frac{N_u - N_1}{N_u - 1} \cdot 100 \quad (8)$$

The intensity of moisture removal of the material was determined, which is 1.3 times greater than in the existing design of the feeder due to the improvement of the processes of mixing and loosening of cotton.

The use of new feeder significantly increases the uniformity of the volume distribution of moisture after drying and, due to this, improves the cleaning of raw cotton during processing on subsequent equipment. At the same time, the quality of the fiber produced by the cotton plant (at processing raw cotton III grade of Bukhara 6varietyof manual picking) increases as a result of a decrease in the content of defects from 3.07 to 2.69%, large trash from 0.66 to 0.45% and small from 0.47 to 0.34%at moisture content of 14.0%.

4. CONCLUSIONS

Heat spent on heating and evaporating the moisture of the dried raw cotton on the proposed equipment is up to 57.0% versus 41%. Due to the preliminary loosening and mixing of raw cotton with a drying agent, it was possible to reduce the temperature loss of spent heating agents. Other heat losses that reduce the coefficient of efficiency of drying are losses with material removed from the dryer, which for existing designs is 11.0%, and for the proposed design is 8.0%. When the dryer is operated with a new feeder, there is a tendency to improve the spinning and technological properties of the produced fiber. According to the results of studies, it was established that the foul of the webs decreased from 161 to 157 pcs per 1 g, elongation increased from 5.6 to 6.4%, relative breaking load of single thread increased from 10.10 to 10.89 g/tack, and foul of the yarn decreased from 110 to 102 pieces per 1 g. Improving the spinning-technological properties of fiber is important factor that should be considered in subsequent experiments.

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