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Experimental analysis of cotton distribution in a drying drum

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Abstract. The moisture efficiency of foreign cotton drying equipment is limited, with only 3-4% improvement, and the cleaning efficiency for small impurities is not substantially higher, reaching only 10-15%. To address these challenges, researchers have explored alternative methods for cotton drying. One such approach involves the use of ceramics as a basis for effective cotton drying, which not only saves electric energy but also ensures high-quality drying. However, this method does not fully address the issue of cleaning the cotton from small impurities during the drying process. The aim is to improve the overall cotton processing efficiency in ginning enterprises, enhancing the quality of the final product and optimizing energy consumption during the drying phase.In this article, the results of experiments on cotton distribution and drying in the actual drying drum are analyzed, the same experiments are carried out on the basis of experiments in a special laboratory for the study of the distribution of cotton in the drying drum, the maximum use of the drop zone of the drum by improving the internal devices of the drum, ensuring that there are no empty zones of cotton in it. Also, the scientific results of placing drum shovels in one row at an angle of φ=5-10-150 with respect to the radius of the drum are presented.

1. Introduction

In the cotton ginning enterprises of the Republic of Uzbekistan, 2SB-10 and SBO authoritative drying drums are used for cotton drying, and a cleaning flow consisting of 1XK and UXK authoritative cleaners is used for cleaning [1]. The moisture efficiency of foreign cotton drying equipment does not exceed 3-4%, and the efficiency of cleaning from small impurities does not exceed 10-15% [2].

It has been found that when the drying process is carried out on the basis of ceramics for effective drying of cotton, it is possible to save the electric energy used for drying, to dry the cotton with high quality, but it is not cleaned of small impurities during the drying process [3]. Many scientific researches have been carried out on the technology of drying cotton, cleaning it from small and large impurities [4-11].

It is known that the new technology of effective cleaning of small impurities in cotton by removing moisture in the process of cotton drying differs from the previous ones in its constructive advantages [5].

Although a number of researchers have conducted studies on improving the uniform distribution and drying of cotton by improving the internal devices of the drum, dividing the inside of the drum into sections, installing shovels in different directions, retarding grids, and changing their sizes, the problem has not been solved. This is due to the fact that the installation of the recommended devices inside the drum prevents the cotton from moving steadily along the axis of the drum and causes it to be heard.

2. Materials and methods

Based on the conducted research and the analysis of the video materials of the movement of cotton in the drum, it was proposed to eliminate the empty zone F1 and to reduce the starting angle of cotton falling from the shovels in order to improve the uniform distribution of cotton in the drum. For this, it was recommended to place the drum shovels in a row, in the direction of the drum radius and with an angle difference of **α** from it (Fig. 1).

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Based on the analysis of video materials, it was determined that the starting angle of cotton falling from the drum shovels is equal to **α=135-140^0**. This cotton corresponds to the natural slope angle **β=45^0**. Parpiev [2, 5, 11] proposed the cotton wetting coefficient, which is determined by the following formula (1).

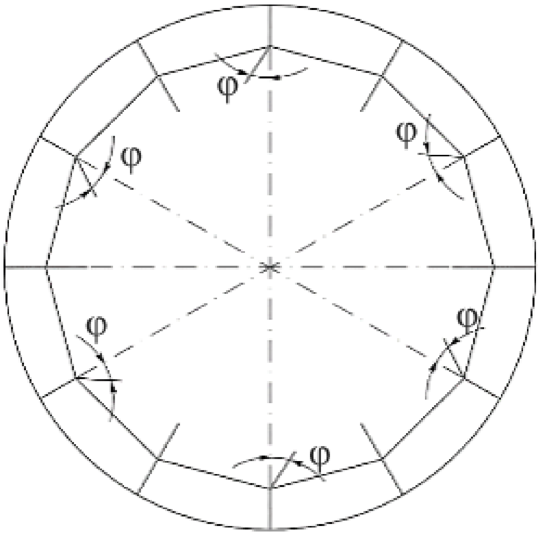

Fig. 1. Location of drum shovels.

$$n_p = \frac{F_f}{F_m} \tag{1}$$

where: F_f is the sum of the surfaces of cotton pieces in contact with hot air, m^2, F_m is the sum of the surfaces that can occupy the maximum of cotton pieces.
Cotton maximum surface:

$$F_m = g_n \cdot S_{kg} = g_n \cdot S_{kg} \cdot n_m \tag{2}$$

where: g_n is the weight of cotton, S_{kg} is the maximum surface of 1 kg of cotton, S_n and n_m are the surface and number of fiber single seed, respectively, $S_n = \frac{\pi \cdot d_n^2}{4} = \frac{3{,}14 \cdot 0{,}16_j^2}{4} = 0{,}2 \cdot 10^{-3}$ m^2 where: d_n is the effective diameter of fiber single seed, m.
The cotton drying coefficient in the drying drum is determined as follows:

$$\mathrm{n}_\tau = \frac{60}{\mathrm{g} \cdot \tau \cdot \mathrm{S}_{kg}} \cdot [(L_b \Sigma bb - \Sigma\delta\delta) + F_L^m \xi^1 m_n] \tag{3}$$

where: g -the productivity of the drying drum for cotton, τ -the time of dividing the cotton in the drum, L_δ -, the length of the drum, m; Σ_{bb} -drying drum cross-sectional surface length of the outer surfaces of the cotton pieces in the cotton drop zone, m; The sum of sections of the outer surface of the cotton lying on the shovels in the cross-section of the $\Sigma_{\delta\delta}$ -drum, m (Fig. 2); ξ^1 –t he coefficient characterizing the increase in the surface of the cotton when it falls from the shovels; m_n- is the number of shovels falling cotton at the same time.
It is determined by the following formula:

$$m_n = \mathrm{m}_{ym} \frac{\alpha_2 - \alpha_1}{360} = \frac{\Delta\alpha}{360} \cdot \mathrm{m}_{ym} \tag{4}$$

m_{ym} = the number of spades in the 12th drum. According to Parpiev [2], the drying speed depends on the n_n -value, and it is based on the fact that its value should not be lower than n_n=0,5. In the drying drum, n_n=0,11 is a very low indicator. Considering that the cotton receives the main heat in the direct contact with the hot air in the drop zone, the maximum use of the drum surface is necessary for the cotton to be drawn. The distribution of the cotton obtained from the experimental equipment in the drying drum is shown (Fig. 2), from which it can be seen that on the cross-sectional surface of the drum, free zones - F1 in the rising zone of drum scoops and F2 - in the falling zone of the scoops are formed from cotton. The formation of these empty zones is caused by the fact that the internal devices of the drum are not able to distribute the cotton evenly, and the cotton is not sufficiently compressed in the drum.

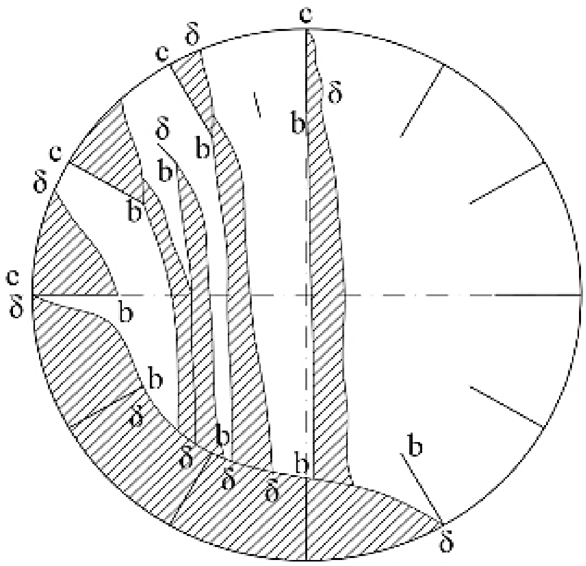

Fig. 2. Cotton distribution in the cross section of the drum.

3. Results and discussion

When the coefficient of cotton is n=1, individual seeds of each fiber in cotton come into contact with hot air and have a maximum heat-receiving surface.

If the diameter of the drum is D=3.2 m, the length is L=10 m, the height of the shovels is 0.5 m, the cross-sectional area of the drum is$F_b = \frac{\pi\cdot d_f^2}{4} = \frac{3,14\cdot 3,2^2}{4} = 8,04$ m^2; and the volume is $\vartheta_b = 8,04\cdot 10 = 80,4$ m^3, the volume of the drop zone is $\vartheta_b = 3,14\cdot 2,2^2 = 38$ m^3, and the volume of the space between the drum blades is equal to $V_к = \vartheta_b - \vartheta_\tau = 80,4 - 38 = 42,4$ m^3.

In this case, it is possible to determine the possibility of changing the coefficient of drying cotton in the drum. The necessary indicators for calculation were determined by formulas. Amount of cotton in bales:

$$g_k = \frac{g\cdot\tau}{60}\left(1 - \frac{m_T}{m_n}\right) \quad (5)$$

The amount of cotton in the drop zone:

$$g_T = \frac{g\cdot\tau}{60}\cdot\frac{m_T}{m_n} \quad (6)$$

The amount of cotton in the drum:

$$g_b = \frac{g\cdot\tau}{60} \quad (7)$$

where m_T is the number of shovels of cotton falling, m_T=2,5; m_n -number of shovels covered with cotton, m_n=7; The time of t-cotton splitting in the drum is τ=6 min.

Fiber single seed size:

$$f = \frac{3,14\cdot d^3}{4} = \frac{3,14\cdot 0,0016^3}{4} = 0,322\cdot 10^{-5} \text{ m}^2$$

The number of seeds in 1 kg of cotton

$$n_n = \frac{1000}{P_n} = \frac{1000}{0,2} = 5000$$

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where; P_n -fiber single seed weight, g

Fig.s 3-4 show the effect of drum capacity on drum quantity, size, and wick ability. It is known that when choosing the technical and economic indicators of drying drums and its main indicators, the productivity is 10-12 t/h, the temperature of hot air is 250-280^{0}C. It is not taken into account that the cotton is soaked in the drum. But the experience of drying drums 2SB-10 and SBO shows that the drying temperature should be reduced to maintain the quality of cotton. In addition, drying drums with a capacity of 12 t/h are used in low cases.

If the cotton that is in the drum at the same time falls evenly in the drop zone, the drying process is faster. As the efficiency of the drying drum increases, naturally the amount of cotton in the drum also increases (Fig. 4). As the coefficient of drying of cotton in the drop zone increases, the surface area of heat absorption also increases, and the drying efficiency improves.

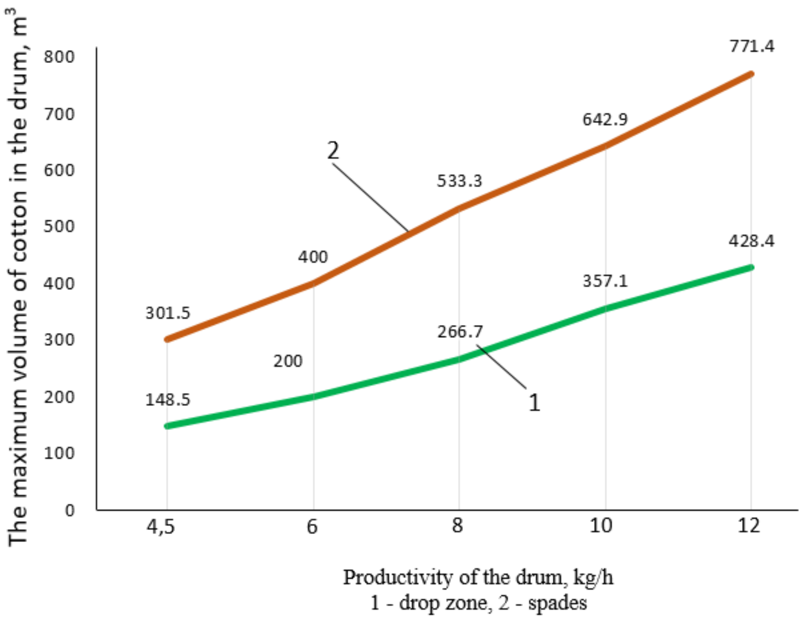

Fig. 3. Dependence of the amount of cotton in the drum on productivity.

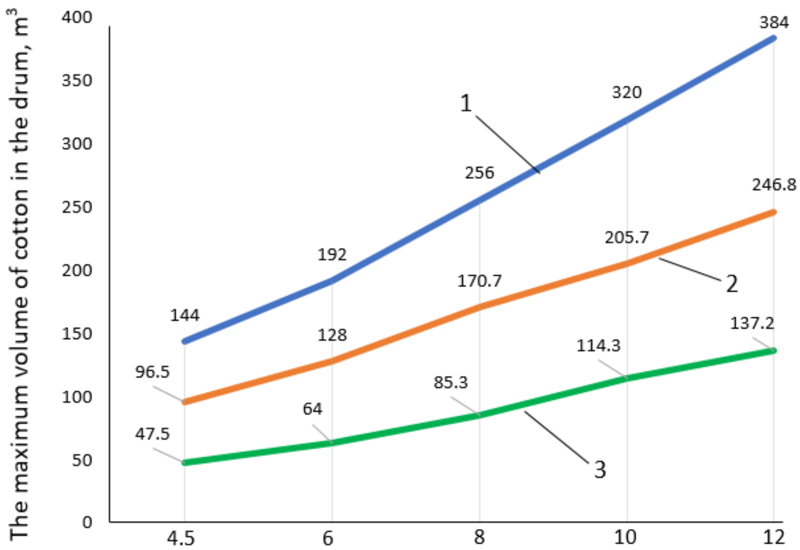

Fig. 4. Effect of drum productivity on the maximum size of cotton.

The analysis showed that when the drying drum performance increased from 4.5 t/h to 12 t/h, the cotton content in the drop zone and scoops increased from 148.5 kg to 428.4 kg and from 301.5 kg to 771.4 kg, respectively. In this case, the share of cotton in the drop zone compared to the amount of cotton in the shovels, the work productivity was constant 0.5 from 4.5 t/h to 8 t/h, and 0.55 at 10-12 t/h.

So, at a work productivity of 10-12 t/h, the number of cottons falling shovels increases and the difference between the starting and ending angles of cotton falling ($\Delta\alpha=\alpha_2-\alpha_1$) increases.

When analyzing the degree of cotton compaction in the drum, first of all, it is appropriate to determine to what extent the possibility of cotton compaction is possible in the volume of the drum.

At the productivity of the drum of 4.5 - 6 - 8 - 10 -12 t/h, the amount of cotton in it is 450 - 600 - 800 - 1000 - 1200 kg, respectively.

Fig. 4 shows the maximum volume of cotton in the drop zone in the drum and in the paddles at different productivity. In this case, the percentage of the maximum volume of cotton in the drop zone compared to the total volume of cotton in the shovel and drum is 0.33 and 0.50, respectively, from 4.5 t/h to 8 t/h, and at 10 and 12 t/h it was found to consist of 0.36 and 0.56. The coefficient characterizing the possibility of drying cotton in the drum was determined by the following formula:

$$n = \frac{v_b}{v_n} \quad (8)$$

It can be seen that as the efficiency of the drum increases, the value of the coefficient n decreases. When the drum productivity changes from 4.5 t/h to 12 t/h, the coefficient n value decreases from 0.56 to 0.21. As can be seen from the obtained graphs, the ideal friction coefficient in the cotton drying drum is also limited, and the productivity is 0.42-0.25 at 6-9 t/h.

In practice, in order to approach this value, it is necessary to improve the internal devices of the drum to maximize the use of the drop zone of the drum, to ensure that there are no empty zones of cotton in it. As can be seen from the obtained graphs, the ideal friction coefficient in the cotton drying drum is also limited, and the productivity is 0.42-0.25 at 6-9 t/h.

In practice, in order to approach this value of cotton drying, improving the internal devices of the drum, making maximum use of the drum's drop zone,ensuring that there are no cotton empty zones in it, these scientific results obtained on the basis of the analysis of the distribution of cotton in the drying drum, allow to use these scientific results to increase the efficiency of drying drums in terms of moisture and dirt.

In experiments, in order to eliminate the free zone F1 in the drying drum, it is necessary to reduce the cotton drop angle α_1, that is, to ensure that the cotton drops earlier. For this, an experiment was conducted by placing the drum shovels in one row at an angle of φ=5-10-150 relative to the radius of the drum.

φ=5⁰ φ=10⁰ φ=15⁰

Fig. 5. The state of filling the cotton between the paddles at different values of the angle of deviation of the drum paddles in the radial direction.

The purpose of the experiment is to fill the free surface F1 with cotton in the drop zone due to the fact that the drop of cotton from the shovels placed at an angle φ starts earlier. The experiments were carried out in the experimental drying and cleaning equipment prepared at the cotton ginning enterprise. The drum consists of 12 shovels with a diameter of 3.2m, a length of 0.5m, and a height of 0.5m. The front of the drum is covered with organic glass and provided with a door for placing cotton. The experiment was carried out on cotton of selection grade An-35 and S-6524 with dirtiness of 7.4%, moisture content of 8.8 and 13.0% at a productivity of 6 - 9 t/h. The amount of cotton put into the equipment at different productivity was determined by the following formula.

$$g = \frac{G \cdot \tau}{60} \cdot \frac{L_b}{L_y} \tag{9}$$

where; G-drum productivity, τ -cotton splitting time in drum, min, L_b and L_y -respectively length of drum and laboratory equipment L_b =10m; L_y =0.5 m;
The distribution of shovels on the surface of the drum at different φ angles was recorded by video and photo, and the surface of the cotton in the drop zone and on the shovels was calculated by planimetric method.
The experimental results are presented in Fig. 5.

Fig. 6 shows the graph of the coefficient of use of the surface of the spade spacing when φ=5-10-15^0, and K_k was determined using the following formula:

$$K_x = \frac{F_k}{F_m} \tag{10}$$

where, the maximum and cotton-covered surfaces between F_m and F_f -shovels, m^2

$$F_m = \frac{V_k}{10 \cdot 12} = \frac{42{,}4}{120} = 0?353 \text{ m}^2$$

The cotton-covered surface F_f between the shovels was calculated planometrically from Fig. 6.

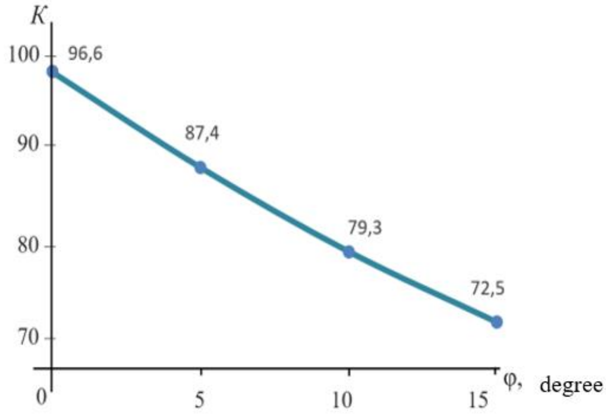

Fig. 6. The influence of the angle of deflection of the blades φ on the coefficient K.

The regression equation of the obtained curve had the following form:

$$Y=0.025X^2-1.985X+96.65$$

Even in the existing option, where the drum blades are located radially, the coefficient K = 96.6% as a result of cotton compaction during the rising of cotton between the blades and the resulting gap between the blades. As the value of angle φ increases, it was observed that the value of $K_к$ decreases from the distance between the blades. The angle was K=87.4% at φ=50 and K=72.5% at φ=150.
Analyzing the distribution of cotton in the drop zone, it can be seen that even at φ=50, the free surface F_1 almost disappears. Taking into account the value of the coefficient of use of the surface between the blades K_k, 6 blades with respect to the radius of the drum φ=50 installation was recommended. It is known that the higher the cotton content in the drying drum, the higher the efficiency of moisture separation and cleaning. In the currently used 2SB-10 and SBO drying drums, the coefficient of cotton shrinkage is equal to 0.11, which is considered a very low indicator. This situation requires conducting scientific research on increasing the quality of cotton in the drum.

4. Conclusions

As the coefficient of drying of cotton in the drop zone of the drum increases, the heat receiving surface also increases and the drying efficiency improves. Analyzes show that when the productivity of the drying drum increases from 4.5 t/h to 12 t/h, the amount of cotton in the drop zone and shovels increases from 148.5 kg to 428.4 kg and from 301.5 kg to 771.4 kg, respectively, it was determined that the percentage of cotton in the drop zone compared to the amount of cotton in the shovels is 0.5, with productivity from 4.5 t/h to 8 t/h, and 0.55 at 10-12 t/h. The percentage of the maximum volume of cotton in the drop zone compared to the total volume of cotton in the shovel and drum, productivity from 4.5 t/h to 8 t/h is 0.33 and 0.50 respectively, and at 10 and 12 t/h It was found to consist of 0.36 and 0.56.

In practice, in order to approach this value of cotton drying, improving the internal devices of the drum, making maximum use of the drum's drop zone, ensuring that there are no cotton empty zones in it, using these scientific results obtained based on the analysis of cotton distribution in the drying drum, to increase the efficiency of drying drums in terms of humidity and dirt;

The analysis of the distribution of cotton in the drop zone revealed that even at φ=50, the free surface F_1 almost disappears, taking into account the value of the coefficient of use of the surface between the shovels, it was recommended to install 6 shovels at φ=50 with respect to the radius of the drum.

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