Simulation of the process of cotton drying under the influence of a heat agent in a spiked-screw cleaner

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Abstract. The spiked-screw cleaner was divided into several sections, and taking into account the same amount of cotton in all sections at the same time, the drying process of cotton in each section was studied from a theoretical point of view. A drying agent was supplied from the upper side of each section, and the process of heat exchange with the cotton rotating and advancing in the spiked-screw was studied. In this case, equations were obtained that indicate that the level of small impurities released from cotton depends on the temperature of the cotton when hitting the heated cotton with piles in each section of the cleaner, moving it on the mesh surface and throwing the cotton up. It was found that the change of the temperature of the cotton fiber depending on the number of sections \( n \) and the air temperature in the open part of the surface \( T_1 \)(K) depending on the screw angle \( \theta \) is close to the law of change of the cotton fiber on a straight line. It was found that the process of moisture exchange in its components depends on the effect of hot air and the drying mode when extracting moisture from cotton moving in a pile-screw cleaner.

1 Introduction

In order to preserve the natural quality indicators of the fiber in the technological process of cotton cleaning and to increase the cleaning efficiency of the equipment, the scientists who studied the heat-moisture indicators of the raw materials in the process of cleaning the dirty compounds in the cotton set the moisture content of the cotton fiber at 5.5÷6.0 % and the temperature at 45÷50°C it is determined that it should be [1, 2].

In the studies conducted by applying heat to the screw cleaner, it was found that increasing the speed of the hot air supplied for drying cotton from 2.5 m/sec to 7.0 m/sec accelerates the process of evaporation of moisture from the cotton content [3, 4]. Also, the cleanness efficiency of the improved equipment has been increased by 7÷8%, and the amount of impurities and defects in the fiber produced in the proposed technological process has been reduced by 0.2÷0.3% compared to the existing technological process [5]. In addition, the

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fuel consumption used for drying high-grade cotton has been reduced by 2.0 times compared to the existing technological process [6, 7].

The process of cleaning cotton from small impurities is mainly carried out in pile-drum and spiked-screw cleaners. The most effective of these two methods is the spiked-screw cleaner, in which the cotton interacts with the piles in the screw and the mesh surface at an arc of 270° on the surface of the cross-section of the spiked-screw, and the process of separating small impurities from the mesh surface is carried out along the length of the screw [8, 9].

If the cotton is at the required temperature during this process, then the process of separating small impurities from the cotton will accelerate and the cleaning efficiency of the equipment will increase, and the quality of the produced fiber will be improved [10-12].

2 Materials and methods

Taking this into account, we will theoretically study the process of cotton drying in the mutual heat exchange of the drying agent with the moving cotton in the spiked-screw cleaner (Fig. 1). In this case, we divide the spiked-screw cleaner into several sections, take into account that all sections contain the same amount of cotton at the same time, and study the process of drying cotton in each section.

We assume that the same amount of cotton is moved in all sections of the spiked-screw cleaner. As the initial section, we take cotton moving in its section. To model the cotton drying process, we adopt the following assumptions:

1. On the upper side of each section, there is an open section, and the drying agent is supplied from this section, and the temperature of the air supplied to dry cotton is constant and equal to $T_1$;
2. In each section of the cleaner, coming into contact with the cotton mesh surface, cleaning of dirty compounds is carried out as a result of the impact and dragging of the piles along the axis of the screw cleaner;
3. Hot air with a temperature of $T_0$ escapes through the holes of the mesh surface;
4. The temperature on the surface of the moving screw cleaner is equal to the temperature of the outside environment;
5. Each piece of cotton stream moves forward and backward in the screw cleaner;
6. In each section, a process of heat exchange takes place between the cotton thrown up and the air, between the cotton and the screw surface according to Newton's law.

Taking into account the above, we consider the cotton moving in the screw as consisting of separate sections similar to $BCD$ [12]. If we direct the $OZ$ axis along the axis of the screw cleaner, we determine the arbitrary coordinate of the piece of cotton moving in the first section of the screw cleaner using the following formula:

$$x = r \cos \theta, \quad y = r \sin \theta, \quad z = \frac{h}{2\pi} \theta, \quad R_0 < r < R_1, \quad 0 < \theta < 2\pi$$

$$\theta_0 < \theta < 2\alpha + \theta_0$$

2 Materials and methods

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Pieces come into contact with the mesh surface. The air temperature $T_1$ in the section $R_0 < r < R_1$, $\theta_0 < \theta < 2\alpha + \theta_0$, is constant and equal to $T_1$, and the temperature of the cotton does not depend on the polar coordinate $r$. Cotton pieces move along the $OZ$ axis and its speed is equal to $v_x = \frac{h\omega}{2\pi}$.

Fig. 1. Scheme of drying process of cotton moving in spiked-screw cleaner sections: 1 - cotton receiving box, 2 - box for discharging cleaned heated cotton, 3 - spiked-screw drum, 4 - mesh surface, 5 - pipe for drying agent, 6 - waste chamber.

3 Results and discussion

Based on the 6 clauses of the accepted hypothesis and the following equations

\[
\frac{dT_{1x}}{dt} = \frac{2\pi}{h} c_v v_x \frac{dT_{1x}}{d\theta} = \frac{2\pi}{h} c_v v_x \frac{dT_{1x}}{d\theta} T_{1x} T_{2x}
\]

We reduce the equations to the following form:

\[dT_{1x} + a_1 T_{1x} = a_1 T_1 \quad \theta_0 < \theta < 2\alpha + \theta_0\]

where:

- $c_v, c_x$ – specific heat capacity of cotton and air
- $\alpha_v$ – convective heat transfer coefficient between cotton particles and air
- $\beta_v$ and $\beta_x$ – Contact heat transfer coefficients of “air-cotton” mixtures of air and cotton particles with mesh surface
- $S_1 = \frac{1-m}{S} S \ S_x = m S$
\[
\begin{align*}
\frac{dT_{2x}}{dT} + c_1 T_{2x} - a_1 T_{2v} &= b_1 T_0, \\
\frac{dT_{2v}}{dT} + c_2 T_{2v} - a_2 T_{2x} &= b_2 T_0
\end{align*}
\]

where:

\[
T_{1x} = T_{nx} \text{ when } \theta = \theta_0 \quad T_{2x} = T_1 \text{ when } \theta = 2\alpha + \theta_0
\]

\[
T_{1v} = T_1 (T_1 (T_0) \exp[\alpha_1 (\theta_0)] \quad T_{2v} = T_0 \text{ when } \theta < 2\alpha + \theta_0
\]

Equations in other sections are similar to (6) and (7) and are integrated under the boundary conditions:

\[
\begin{align*}
\theta = \theta_0, & \quad \text{when } \theta = \theta_0 \\
\theta = \theta_0 + 2\pi, & \quad \text{when } \theta = \theta_0 + 2\pi
\end{align*}
\]

The number of spiked screw cleaner sections and different values of the air temperature change are shown in Figures 1.03057 (2024) E3S Web of Conferences https://doi.org/10.1051/e3sconf/202449703057
The following were accepted in the calculations:

\[ h = 0.3 \text{ m}, \quad \bar{c}_p = 2.5 \text{kJ/m} \cdot \text{grad}, \quad \bar{c}_w = 1.5 \text{kJ/m} \cdot \text{grad} \]

\[ T_0 = 290^\circ K, \quad T_{xn} = 285^\circ K, \quad \omega = 25 \text{c}^{-1}, \quad \alpha_{xy} = 3 \cdot 10^4 \text{kJ/m}^3 \cdot \text{h} \cdot \text{grad}, \]

\[ \alpha = 30^\circ, \quad \beta_x = 10^{-5} \text{kJ/m}^3 \cdot \text{h} \cdot \text{grad}, \quad \beta_v = 1.6 \cdot 10^{-5} \text{kJ/m}^3 \cdot \text{h} \cdot \text{grad} \]

\[ n = 6, \quad n = 12 \]

**Fig. 2.** \( T_1 = 410^\circ K, n = 6, n = 12 \) changes in the temperature of the cotton fiber moving along the screws of the spiked-screw cleaner.

**Fig. 3.** \( T_1 = 420^\circ K, n = 6, n = 12 \) changes in the temperature of the cotton fiber moving along the screws of the spiked-screw cleaner.

4 Conclusions

The spiked-screw cleaner was divided into several sections, and the piles in the screw hit the cotton and made it rotate and advance on the mesh surface around the screw, and the heat exchange during the interaction of the cotton with the drying agent supplied to the cleaner was studied from a theoretical point of view. In each section of the cleaner, the acceleration of the separation of small impurities from cotton depends on the temperature of the cotton when moving the cotton on the mesh surface and throwing it to a certain height. It was determined that the number of sections \( n \) of the pile-screw cleaner and the temperature of the air in the open part of the surface at different values, depending on \( T_1(K) \).
on the screw angle $\theta$, the change in the temperature of the cotton fiber is close to the law of change in a straight line, and the graphs were obtained.

References


