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Process of Heat Transfer in a Drum Dryer for Cotton Raw

Parpiev Azimjon, Yulduz Kupalova

Abstract: ***The article analyzes the process of heat exchange in a drum dryer. A low proportion of the conductive component of heat exchange has been set down due to insufficient heating surface of the drying drum. The heating mechanizm of the drum and the components of raw cotton are determined, a regression equation characterizing the influence of the temperature of the drying agent on their heating rate is obtained.***

Key words - Raw cotton, drum dryer, drying agent, moisture exchange, convective and conductive drying, heat transfer coefficient, fall zone, dam area, uneven heating.

I. INTRODUCTION

One of the main processes of cotton preprocessing contributing to the production of quality products is the drying of raw cotton to the technological level of humidity.

Due to the simplicity of the design and maintenance, a drum dryer with a diameter of 3.2 m, a length of 10 m and longitudinal blades with a height of 0.5 m inside the drum 12 has been widely used for drying cotton.

In a drum dryer, heat exchange occurs between the drying agent - raw cotton, the drying agent - the surface of the drum, the drum's surface - raw cotton, and the moisture exchange between the drying agent and raw cotton.

The process of heat exchange between the drying agent and raw cotton occurs in a convective manner in two versions - in the zone of falling of the raw cotton, when it falls from the surface of the blades and when it is in the area of the roll-off and on the blades.

The processes of mutual heat transfer depend on their temperature, degree of loosening and uniform distribution of raw cotton in the fall zone, as well as on the value of the contact surface of the raw cotton with the shell and the blades.

Earlier researches [1, 2, 3, 4, 5, and others] established technological and regime parameters of a drum dryer, which contributed to increasing their productivity in moisture and cotton.

The amount of heat required to transfer the dried cotton raw, providing a given capacity of the dryer for moisture, according to [6] is determined by the formula

$$Q = \alpha_v * \Delta T_{aver} * V_{drum} * \text{к} \quad (1)$$

where α_v –volumetric heat transfer coefficient characterizing the amount of heat transferred by the coolant of raw cotton, referred to the unit volume of the dryer in $\text{kJ}/(m^3 * \text{h} * \text{grad})$; ΔT_{aver} – average temperature difference between coolant and raw cotton; V_d –drum volume; к –dimensionless coefficient (к = 1,2).

The volumetric heat transfer coefficient α_v is determined by the formula

$$\alpha_v = \alpha_v' + \alpha_v'' + \alpha_v''' \quad (2)$$

where α_v' - heat transfer coefficient, taking into account the heat obtained by raw cotton when it falls from the blades; α_v'' - heat transfer coefficient, taking into account the heat obtained by the outer surface of raw cotton when it is in the blockage and on the blades; α_v''' - heat transfer coefficient, taking into account the transfer of heat from the hot parts of the internal structure and the shell of the raw cotton drum.

$$\alpha_v' = a\alpha_\text{к}' F_c'; \ \alpha_v'' = \alpha_\text{к}'' F_c''; \ \alpha_v''' = \frac{\alpha_\text{к}''' F_\text{к}''' (\text{T}_{aver.\text{к}} - \text{T}_{aver.c})}{\Delta \text{T}_{aver}} \quad (3)$$

where a –coefficient taking into account the decrease in the degree of blowing falling parts of raw cotton, compared with drying in suspension ($a = 0{,}11$); $\alpha_\text{к}'$ - convective heat transfer coefficient to the surface of raw cotton particles falling from blades; F_c' - total surface of the raw cotton particles falling from the blades, referred to 1 m^3 of the dryer drum, m^2; $\alpha_\text{к}''$ - convective heat transfer coefficient for raw cotton, located on the blades and in the blockage in $\text{kJ}/(\text{m}^3 * \text{h} * \text{grad})$; F_c'' - he outer surface of raw cotton located in the rubble and on the blades, per unit volume of the drum, m^2; $\alpha_\text{к}'''$ - heat transfer coefficient from parts of the internal device to raw cotton; $F_\text{к}'''$- total surface of raw cotton in contact with blades and drum shell, m^2; $\text{T}_{aver.\text{к}}$, $\text{T}_{aver.c}$ –respectively, the average temperature of the internal parts of the drum and raw cotton, ^{0}C; ΔT_{aver} – average temperature difference between coolant and raw cotton, ^{0}C.

As can be seen from the formula (3), (4), (5) the values of heat transfer coefficients in the main depend on $a, F_c', F_c'', F_\text{к}'''$ and on the difference $(\text{T}_{aver.\text{к}} - \text{T}_{aver.c})$.

According to [3], the surface area values $F_c', F_c'', F_\text{к}'''$ - per 1m of the drum length is $F_c' = from\ 1{,}05\ to\ 2{,}6\ m^2, F_c'' = 4{,}5\ m^2, F_\text{к}''' = 11{,}2\ m^2$. It can be seen that the contact surface of raw cotton with the drum side shell, where conductive (contact) heat exchange

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***** Correspondence Author (s)
Parpiev Azimjon, Doctor of Technical Sciences, Professor, Tashkent, Uzbekistan
Yulduz Kupalova, Doctoral Student, Tashkent, Uzbekistan.

$F_к'''$is large.

Therefore, it is of practical interest to study conductive heat transfer in a drum dryer.

Figure 1 shows the proportion of heat transfer coefficients of the total obtained from laboratory experiments on a drum dryer with a diameter of 3.2 m and a length of 0.5 m is determined by the formula (3).

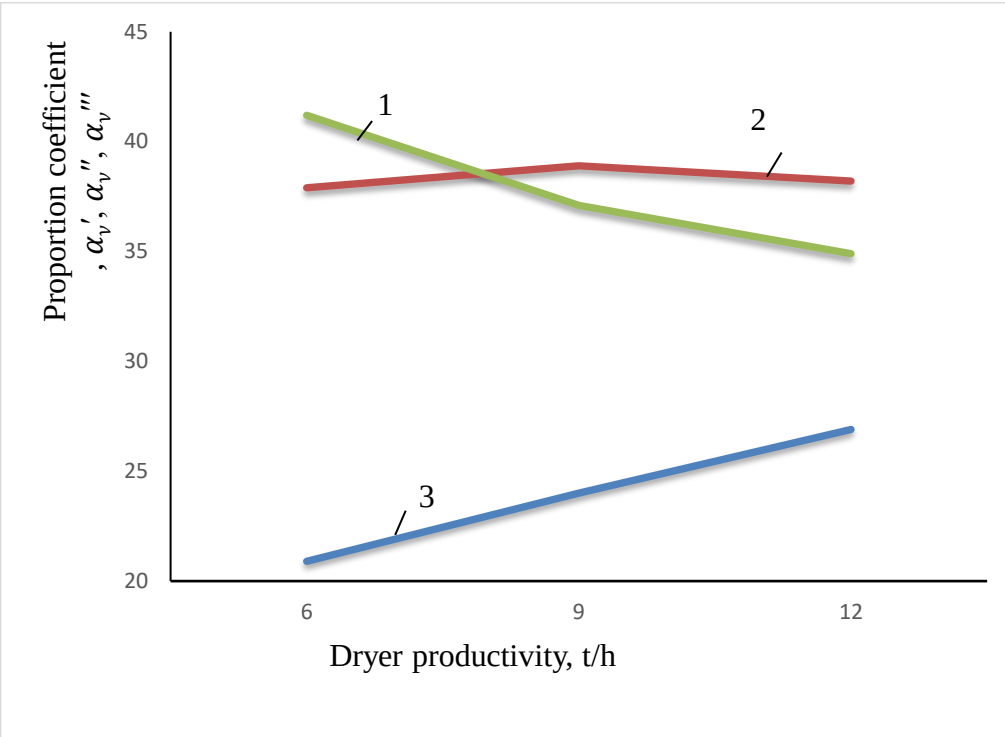

Fig. 1. The effect of dryer performance on volumetric heat transfer coefficients. 1, 2, 3 –accordingly the share $\alpha_v', \alpha_v'', \alpha_v'''$.

From Fig. 1 it is clear that with an increase of productivity, the fractionα_v' decreases, α_v'' - does not change significantly, but α_v''' increases. This is explained by the fact that the amount of raw cotton from the blades increases, the specific surface of the cotton in the drop zone decreases, and the outer surface of the cotton on the blades and in the dam does not change significantly.

The share of α_v''' in heat transfer and raw cotton is low. The increase in its value with increasing productivity is explained by the increase in the surface of contact of the raw cotton with the blades of the drum shell.

Analysis of the operation of the drum dryer showed that there are reserves to increase the intensity of heat and mass transfer in the drum dryer using the convective method of additional heating of the drum shell.

When the raw cotton stays in the drum dryer for 6 minutes, the raw cotton is in the fall zone for 1.5-2 minutes, and the rest is 4-4.5 minutes in the blockage and on the blades, where conductive heat exchange takes place. Using the time of raw cotton in the rubble and on the blades for intensive conductive heat transfer can be achieved by increasing the difference between the temperature of heating - raw cotton and the shell of the drum i.e ($T_{aver.к} - T_{aver.c}$).

In a production conditions was studied drum dryer brand 2SB-10 used in cotton factories of the Republic of Uzbekistan. Drying of raw cotton having different initial humidity at the temperature of the drying agent supplied to the dryer from 40°C to 190°C was carried out, and the heating temperatures of the drum shell, seeds and raw cotton fibers were determined.

II. RESULTS & DISCUSSIONS

The results of the experiments are given in table 1.

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Table – 1
The heating temperature of the drum core fiber and seed

№	The initial moisture content of raw cotton,%	Cotton weed infestation,%	Drying agent temperature, ° C	The heating temperature of the shell drum, ^{0}C							Heating temperature, ^{0}C	
				Drum length, m						Average	Fiber	Seed
				0	2	4	6	8	10			
1	8,8	8,93	40	16	23	23	21	20	20	20,5	20	16
2	12,3	9,3	80	22	38	36	34	32	32	32,3	32	22
3	12,3	9,3	120	30	48	48	45	45	42	43	43	28
4	23,4	18,4	160	55	63	63	60	56	52	58,2	49	32
5	23,4	18,4	190	56	65	65	64	62	57	61,5	54	36

As can be seen from the table 1 drum length is not uniformly heated. When the temperature of the drying agent is up to 120^{0}C, the heating of the drum shell is insignificant (up to 43^{0}C), which means that the difference between ($T_{aver.к} - T_{aver.c}$) is very low, the effect of conductive heat transfer is insignificant.

The regression equation describing the dependences of the heating temperature of the shell of the drum and the drying agent is

$$y = -0{,}0004x^2 + 0{,}367x + 7{,}4 \quad (4)$$

Processing of the results and their analysis of heat exchange between the drying agent, raw cotton and drum shell showed the following.

With increasing temperature of the drying agent, the heating temperature of the drum shell increases, the uneven heating of the drum shell at the temperature of the drying agent to 120^{0}C increases (from 7 to 18^{0}C), then decreases (to 9^{0}C) (fig.2).

Характер изменения температура нагрева обечайки барабана по длине одинакова – до 4 метра повышается, затем снижается.

The character of the change in the heating temperature of the drum shell over the length is the same - it rises to 4 meters, then decreases.

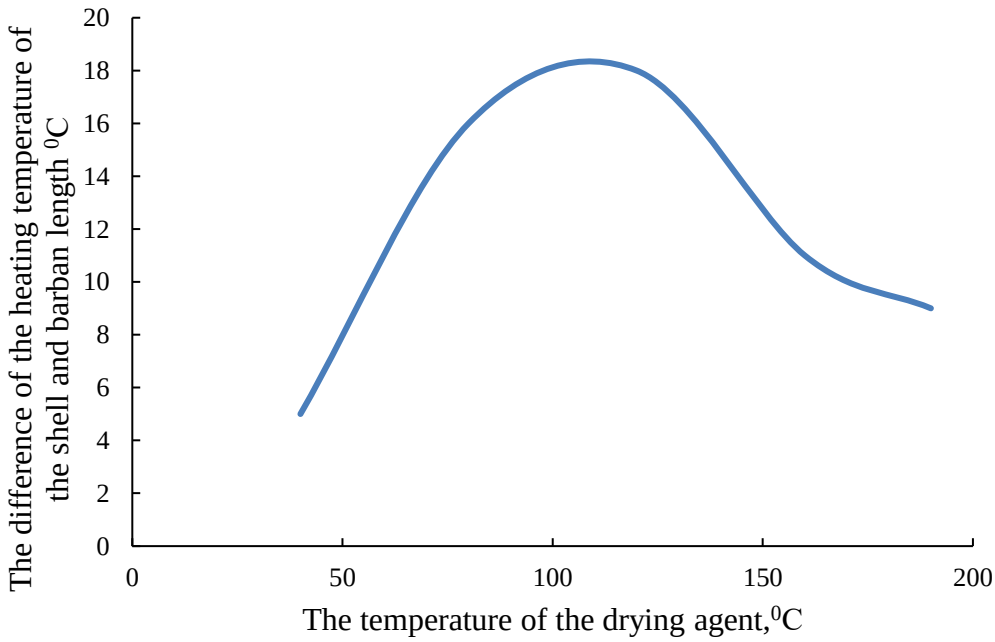

Fig. 2. Irregular heating of the drum surface from the temperature of the drying agent, ° C.

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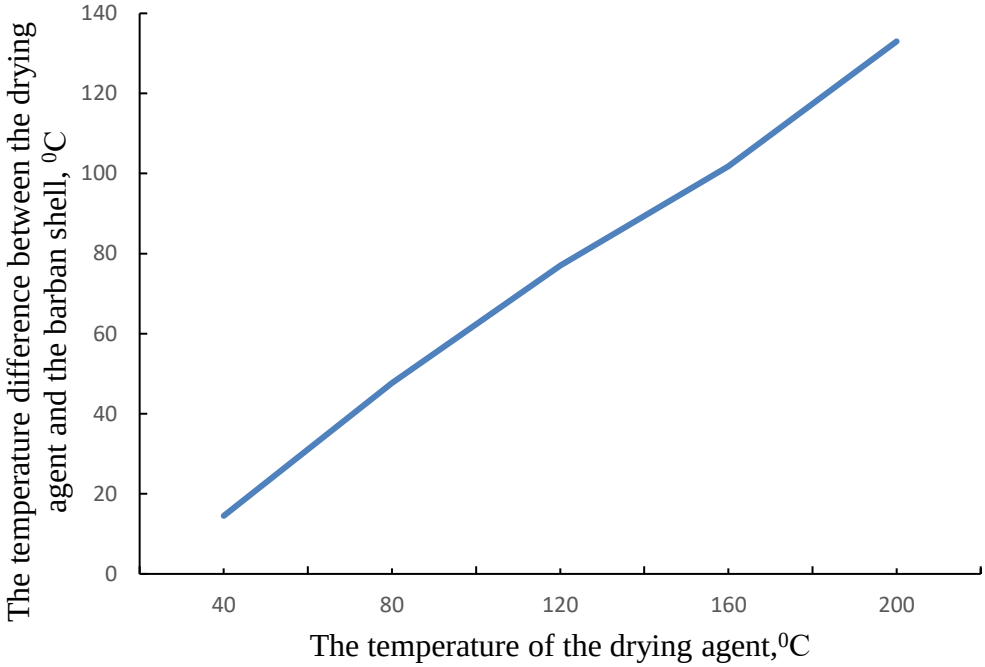

Fig. 3. The change in temperature difference between the drying agent and the drum shell

The difference between the temperature of the drying agent and the drum shell has a certain regularity; with the temperature of the first one, the temperature difference increases (Fig. 3) and describes the regression equation in the form

$$y = 0{,}0002x^2 + 0{,}68x - 07{,}5 \quad (5)$$

Despite the low values of the coefficient x^2, it significantly affects the difference y. When the temperature of the drying agent is from 40°C to 190°C, the value of the temperature difference of the linear dependence of y on the linear differs from 0.5 to 8°C, which is substantial.

The amount of heat that is dropped into the dryer air is spent on the heating of raw cotton and the drum, the evaporation of moisture. Part of the heat goes through the surface of the drum into the atmosphere. The temperature of the air leaving the dryer has a higher temperature than the temperature of atmospheric air, due to which heat loss occurs.

As the drying agent proceeds along the length of the drying drum, its temperature sharply decreases, which does not ensure uniform heating along the length of the drum.

To reduce various heat losses and preserve the quality of the fiber during drying, it is necessary to increase conductive heat transfer between the drum shell and raw cotton by heating the drum surfaces to 70 ° C according to the maximum permissible heating temperature of the fiber [7].

From table 1 it follows that the heating temperature of the fiber and seeds is very low, which indicates a lack of heat exchange rate. If we consider that the bulk of moisture is in the seeds (up to 70%), for intensifying the drying it follows.

From tab. 1 that the heating temperature of the fiber and seeds is very low, at a temperature of the drying agent from 80 to 120^{0}C their temperature after drying is 20-43^{0}C and 16-32^{0}C respectively. This shows the low efficiency of the drum dryer at a drying temperature of up to 120° C.

From fig. 3 it follows that the heating rate of the components of raw cotton is low, the irregularity of their heating is high. With increasing temperature, the temperature difference between fiber and seed increases.

The regression equation for their temperature is obtained.

For fiber

$$t_т = -0{,}0009t_в^2 + 0{,}436t_x + 4 \quad (6)$$

For seed

$$t_c = 0{,}1333t_в + 11{,}7 \quad (7)$$

where $t_в$ - drying agent temperature.

From the results obtained, the following conclusions are drawn:

1. It has been analyzed that despite the large surface of conductive heat exchange between raw cotton and drum sidewall (11.2 m^2 per unit length of the drum), its specific proportion of the total amount of heat perceived by raw cotton is low (from 20.9 to 26.9) , which show the available reserves to increase the intensity of heat transfer.
2. Conducted research in a production environment showed the following:

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- The heating temperature of the dryer drum side is uneven and insufficient. Its value rises to 4m, the length of the drum and then decreases;
- The heating rate of the components of raw cotton and seeds is low, which reduces the drying efficiency. A regression equation is obtained which characterizes the influence of the temperature of the drying agent on the heating temperatures of the fiber and seeds, as well as the drum shell.

To intensify the process of heat exchange and drying of raw cotton, it is necessary finding out ways to increase the efficiency of conductive heat exchange with the use of additional heating of the drum shell.

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