The raw cotton entering volume computational and numerical study of the vertical-spindle cotton harvester receiving chamber

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Abstract. The article presents a computational-and-numerical study of raw cotton entering the receiving chamber per one second. Numerical calculations were conducted of the change in the volume of raw cotton entering the receiving chamber depending on the yield ripeness and the completeness of the machine harvest. The volume of raw cotton entering the receiving chamber during cotton harvesting was determined, depending on the width of the cotton row spacing. The calculation results showed that for a serial receiving chamber, the volume of cotton filling the receiving chamber should not exceed 0.0031 m^3 per second; otherwise the receiving chamber is clogged, and the loss of cotton to the ground increases.

1 Introduction

At present, a one-time technology for machine harvesting of cotton is used. One-time technology of machine harvesting is realized when more than 90% of cotton bolls are opened. With this technology, the load falls on the pneumatic transport system of the cotton harvester. For a domestic cotton harvester, an urgent task is to determine the yield limit at which the pneumatic transport system can transport raw cotton without losses to the ground and the clogging of the receiving chamber.

The operation of pneumatic transport systems of domestic cotton harvesters is studied in the research institutes of the Academy of Sciences of the Republic of Uzbekistan; CNIIH Proma; SAIME; TashPI; GSKB on machines for cotton farming [1-17].

However, in the published articles, the issues of the one-time harvesting technology are not sufficiently covered, in which the pneumatic transport system can transport raw cotton without losses to the ground and the bottom of the receiving chamber.

According to A.G. Arzumanyants et al. [9], the air velocity in the receiving chamber must be at least 25 m/s; otherwise, the receiving chamber will be clogged with cotton.

It is known that in a serial receiving chamber, raw cotton, overcoming the force of gravity, moves to the upper part of the receiving chamber. Therefore, in the lower part of the receiving chamber, the air flow rate must be higher than $\upsilon_b \geq 6$ m/s [18]. In the

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experimental option of the receiving chamber developed, raw cotton, on the contrary, moves from top to bottom. As a result, the required air volume for transport will be less compared to serial receiving chambers.

According to the requirements of the GSKB on machines for cotton growing, at a mixture concentration of $\mu = 0.2$ in each air pipe, the air volume should be Q=0.55 m^3/s.

In bench tests of the experimental option of the receiving chamber, the volume of air flow when transporting cotton into one air pipe was Q=0.425 m^3/s.

In this regard, it is necessary to determine the volume of raw cotton filling the receiving chambers of the serial and experimental options per one second.

The aim of the study is to determine the allowable volume of raw cotton filling the receiving chambers of the serial and experimental options, which ensure the transportation of raw cotton without loss to the ground and without clogging the receiving chamber.

2 Methods

Computational and numerical study of the volume of raw cotton entering the receiving chambers of the serial and experimental options of the vertical-spindle cotton harvester.

3 Results and Discussion

According to the design dimensions presented in Figure 1, the volumes of the receiving chambers of the serial and experimental options are the same and equal to [7,19]:

$$V_{PK} = a \cdot в \cdot н, \quad m^3 \tag{1}$$

where: a – is the length of the receiving chamber *(*a = 0.158 m); b – is the width of the receiving chamber (b = 0.124 m); h – is the height of the receiving chamber (H = 0.62 m).

According to expression (1), the volume of the receiving chamber is:

$$V_{PK} = 0{,}158 \cdot 0{,}124 \cdot 0{,}62 = 0{,}0121 \quad m^3$$

The change in the flow of raw cotton mass into the receiving chamber per second is determined according to [20].

Raw cotton entering the receiving chamber per one second is determined by the following formula:

$$G_{\text{m}} = \frac{G_p \cdot B \cdot V_{\text{m}} \cdot P}{n \cdot 10^4}, \quad kg/s \tag{2}$$

where: G_p - is the open cotton bolls yield per hectare (G_p= 2000 ÷ 5000 kg/ha); B – is row spacing (B = 0.6 m, B = 0.9 m); V_m – is machine speed V_m = 4.2 km/h = 1.16 m/s; P – is completeness of machine harvesting (P = 0.88 ÷ 0.93); N – is the number of suction pipes when harvesting from one row (n = 2).

The change in the volume of raw cotton is determined from the expression:

$$V_{\text{hl}} = \frac{G_m}{\gamma}, \quad m^3 \tag{3}$$

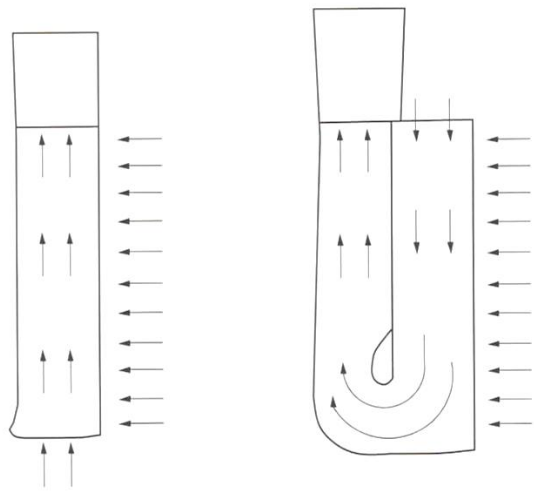

Fig.1. Receiving chambers of the cotton harvester: a) serial option, b) experimental option

According to [21], the density of raw cotton γ is assumed to be γ = 50 kg/m^3.

Based on expressions (1) - (3) and the initial data, the yield and completeness of the raw cotton harvesting, depending on the width of the row spacings, are presented in Tables 1 and 2.

Table 1. Influence of cotton bolls opening and completeness of the harvesting on the volume of cotton entering the receiving chambers at a row spacing B = 0.6 m

G_p, kg/ha		2000	2500	3000	3500	4000	4500	5000
V_{pk},m^3		0.0121						
G_m, kg/ha	P=0.88	0.060	0.076	0.091	0.106	0.121	0.136	0.152
	P=0.91	0.062	0.078	0.093	0.109	0.125	0.141	0.157
	P=0.93	0.064	0.080	0.096	0.112	0.128	0.144	0.160
V_{hl}, m^3	P=0.88	0.0012	0.0015	0.0018	0.0021	0.0024	0.0027	0.0030
	P=0.91	0.00122	0.00158	0.00186	0.00218	0.0025	0.0028	0.0031
	P=0.93	0.00128	0.0016	0.00192	0.00224	0.00256	0.00288	0.0032

Table 2. Influence of cotton bolls opening and completeness of the harvesting on the volume of cotton entering the receiving chambers at a row spacing B = 0.9 m

G_p, kg/ha		2000	2500	3000	3500	4000	4500	5000
V_{pk}, m^3		0.0121						
G_m, kg/ha	P=0.88	0.090	0.114	0.136	0.159	0.181	0.204	0.228
	P=0.91	0.093	0.117	0.139	0.163	0.187	0.211	0.235
	P=0.93	0.096	0.120	0.144	0.168	0.192	0.216	0.240
V_{hl}, m^3	P=0.88	0.0018	0.0023	0.0027	0.0032	0.0036	0.0041	0.0046
	P=0.91	0.00186	0.00234	0.0028	0.0033	0.0037	0.0042	0.0047
	P=0.93	0.0019	0.0024	0.0029	0.0034	0.0038	0.0043	0.0048

Since the volume of the receiving chambers of the serial and experimental options is the same, the volume of cotton in them will also be the same.

Analysis of data from Tables 1 and 2 shows that when picking cotton at a row spacing of B = 0.6 m with an increase in the open bolls yield Gp = 2000 ÷ 5000 kg/ga, the ratio of the volume of the receiving chamber to the volume of cotton entering the receiving chamber changes at a completeness of the harvesting P = 0, 93 within 9.45 ÷ 3.78 times, and, accordingly, at a row spacing of B = 0.9 m, at P = 0.93, it changes within 6.72 ÷ 2.52 times.

Analysis of Tables 1 and 2 shows that the volume of raw cotton entering the receiving chamber when picking cotton at a row spacing of $B = 0.9$ m is 1.5 times greater than the volume at a row spacing of $B = 0.6$ m.

Based on the proposed recommendation of the GSKB on machines for cotton growing, at $Q = 0.55\ m^3 / s$, $\mu = 0.2$, we define the cotton open bolls yield criterion. For this, we determine the mass of cotton filling the receiving chamber per one second at $\mu = 0.2$, $Q = 0.55$ m^3/s.

$$G_m = \mu \cdot Q \cdot \gamma = 0.2 \cdot 0.55 \cdot 1.29 = 0.142\ kg$$

According to expression (1) and the completeness of machine harvesting $P = 0.85$ at a row spacing $B = 0.6\ m$

$$G_P = \frac{G_m \cdot P \cdot 10^4}{B \cdot V_m \cdot n} = \frac{0.142 \cdot 2 \cdot 10^4}{0.6 \cdot 1.16 \cdot 0.85} = 4802\ kg / ga$$

At a row spacing $B=0.9\ m$

$$G_P = \frac{G_m \cdot P \cdot 10^4}{B \cdot V_m \cdot n} = \frac{0.142 \cdot 2 \cdot 10^4}{0.9 \cdot 1.16 \cdot 0.85} = 3201\ kg / ga$$

According to Table 1, for a row spacing $B = 0.6\ m$ with the open cotton bolls yield $Gp = 4802\ kg/ga$, the volume of raw cotton filling the receiving chamber per one second is V_{hl}=0.0031 m^3, according to Table 2 for a row spacing $B = 0.9\ m$ with the open cotton bolls yield $Gp = 3201\ kg/ga$, the volume of raw cotton filling the receiving chamber per one second is V_{hl} =0.0031 m^3.

Summarizing, we can state that with the air flow rate $Q = 0.55\ m^3/s$ of one pipeline during the transportation of raw cotton to the serial receiving chamber, the volume of raw cotton filling the receiving chamber above $V_{hl} \geq 0.0031\ m^3$ per second leads to an increase in cotton loss to the ground and the clogging of the receiving chamber.

In this regard, a decrease in the volume of the ratio of the receiving chamber to the volume of cotton filling the receiving chamber by $K \leq (0.0121:0.0031) = 3.9$ times leads to an increase in the loss of cotton to the ground and the clogging of the receiving chamber. In the experimental receiving chamber, it is possible to transport raw cotton without loss of cotton to the ground and the clogging of the receiving chamber at $\mu = 0.5$ and the air flow rate of one pipe $Q = 0.425\ m^3/s$ due to the raw cotton movement from top to bottom inside the receiving chamber.

Let us calculate the criterion for cotton open bolls yield according to the following formula:

$$G_m = \mu \cdot Q \cdot \gamma = 0.5 \cdot 0.425 \cdot 1.29 = 0.274\ kg$$

According to Table 2, for row spacing $B = 0.9\ m$ and completeness of machine harvesting $P= 0.93$, the cotton open bolls yield is $Gp = 5500\ kg /ga$. This corresponds to the volume of cotton filling the receiving chamber $V_{hl} \geq 0.0054\ m^3$.

According to the above results and the data of Tables 1 and 2 (*B = 0.6, B = 0.9, P = 0.93*), a graph is plotted, see Figure 1.

Analysis of the graphs in Figure 1 shows that an increase in the volume of raw cotton filling the serial receiving chamber above V_{hl} ≥ 0.0031 m^3per second is impractical due to an increase in the loss of cotton to the ground and the clogging of the receiving chamber.

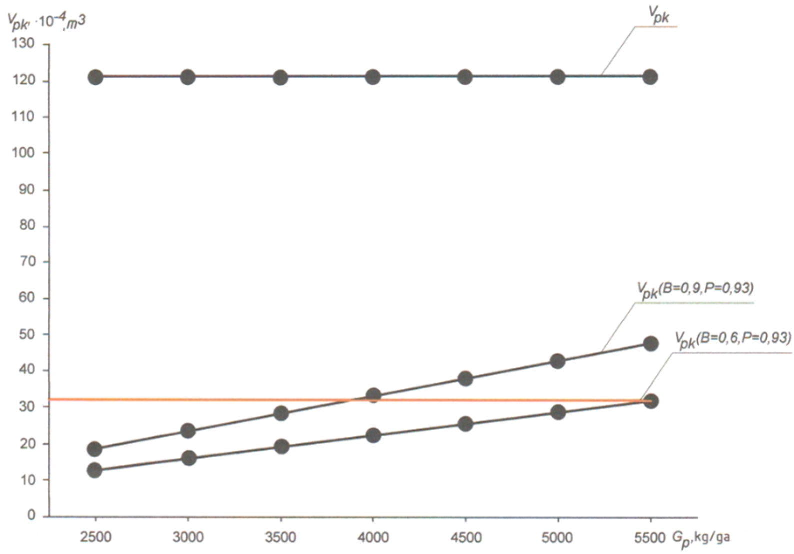

Fig. 2. Change in the volume of raw cotton entering the receiving chamber depending on the cotton open bolls yield

4 Conclusions

To ensure the efficient operation of the pneumatic transport system of the cotton harvester, in calculations, it is necessary to take into account the completeness of the machine harvesting *P = 0.93* at a row spacing *B = 0.9 m* and an open bolls yield *Gp = 5000 kg/ga*. With this technological mode, raw cotton entering the receiving chamber fills its volume to the maximum.

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