Crushing of cottons under the influence of teeth roll in combined aggregate

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Abstract. Object of research consists of the morphology of cotton stalks, physical and mechanical properties of cotton and cotton soils, interaction with the gear roller and its cotton stalk in the combined aggregate. Taking into account the need for alternate and short-term technological processes of cotton stalk harvesting, tillage and cotton picking, a new technology for the formation of new stalks and stalks in cotton fields and a combined unit for its implementation has been developed. The article presents materials devoted to substantiating the parameters of the gear reel of this combined unit. Because the crushing of cotton stalks is an important factor that determines the quality of this technology. The use of the existing working part of the unit for the purpose of crushing cotton stalks at once indicates the perfection of the design. To carry out the process of crushing the stalks, without removing them from the pile, lay them on the pile surface in the direction of movement of the unit, and then crushing is carried out with the teeth mounted on the base wheel of the combined unit. The results of theoretical and experimental research show that the amount of crushing of cotton stalks is higher when the tooth thickness is 3.5 mm and the shape of the blade is curved.

1. Introduction

The object of research is the morphology of the stalk, the physical and mechanical properties of the stalk and stalk soil, the toothed roller in the combined aggregate and the processes of its interaction with the stalk.

Although all technological processes in cotton growing are mechanized, most of them are limited to performing a single technological process [1,2,3,4]. The result is an increase in the type and number of equipment and their number in and out of the field [5,6,7]. As a result, fuel and labor costs have increased, and due to the short duration of technological processes, it is not always possible to perform them on time [8,9,10]. Most importantly, the soil began to lose its existing properties from various mechanical influences, including compaction and declining productivity. By the XXI century, farmers of our republic, like all mankind, have changed their attitude to the soil. The number of different manifestations of tillage is declining sharply, with particular emphasis on minimal and zero technologies [11,12,13].

Theoretical and practical analysis shows that after the cotton is harvested, there are technical means to grind the cotton stalks with the roots and leave them on the field surface or to scatter them in the field [14,15,16]. However, burying the crushed cotton stalks on the surface of the field is done only by plowing. This is done by using two separate techniques that are not related to each other. In addition, in areas where cotton is grown on cotton, the technology of digging cotton stalks without crushing the
roots, placing it on the side furrow, and then on it to form cotton and a combined unit that implements it has also been developed [17,18]. Field tests on this combined unit have shown that it is advisable to crush the stalks and then bury them [19,20].

Based on the above, the aim of the study was to substantiate the parameters of the gear roller, which lay and crush the stalks in the direction of movement on the surface of the stalk without tearing them.

The task of the study was to substantiate the parameters of the roller teeth in the combined aggregate on the process of crushing the stalks.

2. Materials and methods
Combined aggregates for preparing the ground for planting around the world, machines that grind cotton on the surface of the pile without tearing, digging the cotton stalk and then crushing and scattering on the surface of the field, the research and 40-year patent-information study and analysis of the results and methods of analysis of the results and the rules of classical mechanics were carried out on the design and technological process of cotton picking machines, which simultaneously grind cotton and scatter it on the field. Based on the analytical results, a gear roller with a simple design, compact size, small metal capacity and reliable performance of the technological process was formed. Because the toothless rollers were part of the combined aggregates. They are designed to act as a base wheel in the unit and are designed to move on the edge. The authors, on the other hand, placed a tooth on this reel and designed it to move on the surface of the reel.

3. The study of the structure of the modified lead-tin-base bronze
Based on the results of many years of scientific-theoretical and experimental research analysis, the technology of formation of new clumps and opening of branches buried in the cotton fields under the crushed cotton stalks and the combined aggregate scheme for its implementation was developed. A two-row experimental-industrial version of the unit was prepared for the combination and field tests were conducted.

The proposed technology is implemented by performing the following processes (figure 1). 1. Figure a shows a schematic of a cotton field. Initially, the cotton stalks are crushed and compacted on the surface of the pile (Fig. 1, b). The \textit{ABVGD}-shaped stalk, where their root is located, is then cut and placed on the lateral edge (Fig. 1, c). Field 1, g- will have the appearance shown in Fig. The \textit{EABVGDLS}-shaped bottom layer of the existing ridge is divided into \textit{EABVDS} and \textit{DSVGL}-shaped ridges, each of which is rolled over the stalks on the left and right ridges separately. As a result, new shoots are formed in place of the old shoots, buried in the crushed cotton stalks, and new shoots are formed in place of the old shoots. Once the technology is implemented, the field will have the appearance shown in Figure 1, d.

Carrying out the above processes in the fall at once saves time, material and energy resources in cultivating the soil and preparing it for planting.

New piles and ridges are formed in one pass due to minimal tillage of the soil. Most importantly, it is possible to grind cotton stalks without significant energy consumption.

A scheme of the combined unit, which implements the proposed technology, consisting of a guide, a gear roller, a lemex, an auger and a screwdriver, was developed (Fig. 2).
Figure 1. The Scheme of technology for obtaining and germinating new cotton in cotton fields: a-cotton field scheme; b-scheme of crushed cotton stalks on the surface of the pile; v-is the cross-sectional area of the stalk of the stalk where the root of the stalk is cut with the soil; g-placement of the cuttings on the sidewall; diagram of d-formed new ridges and ridges profiles.

Figure 2. The schematic of a combined unit: 1-frame; 2-hanging device; 3-router; 4-toothed roller; 5-lemex; 6-auger sheath; 7-screw; 8-pushtalolgich; 9-adjustment screw; 10-chain extension; 11-hydmotor.
The materials presented in the article are devoted to substantiating the parameters of the gear roller in the composition of the combined unit. Because the proposed technology begins with the process of crushing cotton stalks.

Studies on the gear roller have been devoted to substantiating parameters such as the shape of the cross-section of the blade of the teeth and the vertical load on the gear roller.

Cotton stalks belong to the group of anisotropic materials with low elasticity and plasticity of agriculture. Therefore, depending on the shape of the cross-section of the affected working part blade, the stalks can be cut and crushed.

Taking into account the above, we consider the conditions under which the processes of crushing and breaking of cotton stalks laid on the surface of the pile under the influence of a toothed roller Figure 3.

![Figure 3](image)

**Figure 3.** Scheme for determining the forces acting on the stalk when the shape of the toothed roller is arched.

In conducting theoretical research on the impact on cotton stalks with a toothed roller, the following permits were adopted:

- rolls without slipping and cracking during the movement of the gear roller;
- the linear velocities of the unit and the tooth during the movement are equal, the surface on which the cotton is laid is flat and hard.

Optional $a$ point of the toothpick $β$ compresses the $m$ particle of the cotton stalk in the direction of velocity with normal $Q$ force. The normal force $Q$ can be divided into the forces forming $Q_t$ in the direction of the velocity of a point, $Q_τ$ directed in the direction of the attempt made on it (Fig. 3). There is also a frictional force $F$ between the blade arc and the cotton stalk, and it is reversed by the force $Q_τ$.

As can be seen from Figure 3,

$$Q_τ = Qtgψ. \tag{1}$$

The force $Q_τ$ forces the $m$ particle of the stalk to slide along the working surface. The frictional force $F$ resists its sliding. The description of the motion of a stalk $m$ particle depends on the interaction of the angles $ψ$ and $φ$. The frictional force $F$ resists its sliding. The description of the motion of a stalk $m$ particle depends on the interaction of the angles and $φ$. For example, in the case of $ψ < φ$, the relationship between the forces is as follows,

$$Q_τ = Qtgψ < F_{max} = Qtgφ. \tag{2}$$

(2) by expression the $m$ particle of the stalk does not slide along the working surface. This is because the frictional force $F$ resulting from the force $Q_τ$ cannot reach its maximum value and remains equal to the force that generated it as the reaction force, that is, $Q_τ=F$. In this case the two forces are mutually balanced and the $m$ particle remains under the influence of only one $Q_τ$ force. As a result, the particle $m$ moves along the point $a$ of the blade arc along its absolute velocity $β$, i.e. the cotton stalk is crushed (Fig. 3).
If $\psi > \phi \Rightarrow Q_{tg} \psi > Q_{tg} \phi$ comes from $Q_{tg} \psi$ becomes $Q_{tg} \phi$. In this case, the friction force $F_{max}$, which has reached its maximum value, fails to balance the force $Q$. As a result, the crushing of the stalk occurs under the influence of the force $Q$, only the sliding of the particles is observed by the difference of the forces $Q_{tg} \phi$ and $F_{max}$, i.e. $Q_{tg} \phi - F_{max} = Q(tg \psi - tg \phi)$.

Under the influence of the teeth, the stalk is not only crushed, but also broken, because the stalk does not stretch, as can be seen from Figure 3, the distance $aS$ is longer than $aD$. This condition can vary depending on the number of teeth.

One of the important physical and mechanical properties of cotton stalks is the limit of their crushing resistance, which is usually characterized by the crushing stress $P_{\nu}$ $(N/cm^2)$ and is expressed as follows,

$$P_{\nu} = \frac{Q_{tg}}{S}$$  \hspace{1cm} (3)

where $S$–is the cross-sectional area of the tooth blade, $m^2$.

In order to crush the cotton stalks, the following condition must be met,

$$[P_{\nu}] \leq \frac{Q_{tg}}{S}$$  \hspace{1cm} (4)

Based on expressions (3) and (4) and taking into account the average value and humidity of the number of stalks exposed to the tooth at the same time,

$$[P_{\nu}] \leq \frac{Q_{tg}}{nS} \left(1 + \frac{W}{100}\right)$$  \hspace{1cm} (5)

or

$$Q_{tg} > \frac{n[P_{\nu}S]}{1 + \frac{W}{100}}$$  \hspace{1cm} (6)

where $S = \pi \cdot r \cdot b_{f}$–the impact surface of the toothpick on the cotton plant, $m^2$; $r$–the radius of the tooth arc, m; $b_{f}$–the width of the impact of the toothpick on a single stalk (according to the diameter of the center of gravity of the stalk), m; $n$–the number of stalks that interact with the toothpick, pcs; $W$–moisture of cotton stalks, %.

The radius of the tooth arc $r = 0.00175$ m, $b_{f} = 0.006$ m dimensions, humidity $W = 39\%$ and $[P_{\nu}] = 3.5 \cdot 10^6$ Pa and $n = 10$ 830 N force is required to crush the stalks when calculated according to expression (6). $Q_{tg}$ in calculations by expression $\pi = 3.14$, $r = 0.00175 - 0.00275$ m, $n = 10$, $b_{f} = 0.006$ m, $[P_{\nu}] = 3.5 \cdot 10^6$ Pa and $W = 20 – 60\%$ accepted and the graph in Figure 4 was constructed.

![Figure 4](image_url)

**Figure 4.** Graph of changing in the force expended on crushing the stalk depending on the radius of the tooth blade arc: 1-$W=35\%$; 2-$W=45\%$; 3-$W=55\%$

The graphical analysis in Figure 4 shows that the amount of force expended to crush the tooth blade increases with increasing radius.

The amount of force expended to crush the stalk and the radius of the tooth arc are related by a linear pattern.
Theoretical studies were also continued for the condition when the tooth blade had an acute angle (Figure 5).

\[ P_{\text{ch}} < \frac{2Q}{\delta \cdot b \cdot n} \left(1 + \frac{W}{100}\right) \]  

\( \delta = h_1 \cdot \tan \beta \)  

\[ [P_n] < \frac{2Q}{h_1 \cdot \delta \cdot b \cdot n} \left(1 + \frac{W}{100}\right) \]  

or

**Figure 5.** A scheme for determining the forces acting on a cotton swab when the shape of the tooth blade is acutely angled

**Figure 6.** Scheme for determining the cross section of a toothpick

Considering the relationship between the depth \( (h_1) \) and the angle of sharpness \( (\beta) \) of the toothpick and its thickness \( (\delta) \) in Figure 6,
where $\delta$—tooth blade thickness, m; $\beta$—sharpness angle of tooth, degree.

Given that the size of the tooth is $h_1=0.015$ m, $\beta=30^\circ$, $b_1=0.006$ m, the humidity is $W=39\%$ and $[P_\tau]=3.5\cdot10^6$ Pa and $n=10$ pieces, to crush the stalks when calculated according to expression (10) 654 N power is required.

In the calculations $h_1=0.015$ m, $\beta=30-60^\circ$, $n=10$ pieces, $b_1=0.006$ m, $[P_\tau]=3.5\cdot10^6$ Pa and $W=20-60\%$ are taken and the graph in Figure 7 according to the expression (10) was built.

![Graph of the force applied to the crushing of the stalk depending on the sharpness angle of the toothpick: 1-W=35 %; 2-W=45 %; 3-W=55 %](image)

The graph in Figure 7 shows that the force exerted on crushing the stalks is connected to the sharp corner of the tooth blade according to the law of the sunken parabola.

The graphical analysis shows that the value of force expended on crushing the stalks increases as the sharpening angle of the blade increases.

Also from this graph, it can be seen that the smaller the sharpening angle of the toothpick, the more likely it is that the stalks will be cut rather than crushed. This indicates that the situation does not fit the intended purpose.

4. Conclusion

Based on the results of the research, the following conclusions were made:

1. The technology of creating new shoots on the crushed stalks placed at the bottom of the existing shoots and in place of the existing shoots creates the opportunity to protect the soil, save energy and resources.

2. In relation to the machine for digging cotton stalks for use as an organic fertilizer, and then for threshing in the field, laying them on the ground and crushing is provided by a gear with a simple structure and small metal size.

3. It is possible to crush the stalks when the height of the toothed roller is 30-40 mm and the cross section is arched.

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