On improving productivity of a combined cotton picker

R D Matchanov¹, and A I Yuldashev²

¹ «Agrixim» JV, Sultanali Mashkhadiy street, h. 210, city of Tashkent, Republic of Uzbekistan.
² “Uzagroteksanoatholding” Holding Company, Buyuk Ipak street, 434, city of Tashkent, Republic of Uzbekistan.

E-mail: raf1942@mail.ru

Abstract. The article presents the results of research on increasing productivity of a cotton picker by increasing capacity of the bin for accumulating cotton. A technology and bladed firmer were developed for local, layer-by-layer cotton compaction separately in the back and front of a hopper. The modes of operation of the compactor and the required length of furrow have been established, which allow collecting a full basket without manual ramming of cotton. The proposed solutions made it possible to increase the capacity of the cotton picker basket 1.4-1.6 times. Productivity of the machine has increased by 10-15%.

1. Introduction

One of the main factors constraining productivity increase of cotton pickers is insufficient capacity of a basket [1].

Based on the degree of opening the cotton bolls, cotton harvesting is carried out by vertical-spindle (with the opening by 55-60%) or horizontal-spindle (with the opening by 85-90%) cotton pickers [2]. Moreover, cotton harvest with the opening by 55-60% of bolls is carried out in two passes of the machine, and with the opening by 85-90% or more in one pass [3].

The cotton growing in Uzbekistan is in the northern risky farming zone [4].

In the past several decades, due to various reasons, including global warming, the opening of cotton bolls has accelerated. For example, when the machine cotton picking began in 1980-1990, the average opening of cotton bolls was 70%, and in 2008-2018 it already reached 91.6%. Now it is possible to harvest the entire cotton crop in one pass. This means that the share of horizontal-spindle cotton picking (in one pass) will increase [5].

Increasing the productivity and quality of machine cotton picking was considered in the works of A.A. Rizayev [6], A.D. Glushchenko, M.T. Tashbolyayeva [7], R.I. Spevakova [8], Glushchenko A.D. et al. [9], O.S. Jabbar [10]. The works of A.D. Abdazimov [11], T. Yuldashev, A.A. Rizayev, A. Isamitdinov [12], A.A. Rizayev, R.R. Khudaykuliyev, A.R. Khudzhaev [13] are devoted to development of working bodies of a cotton picking machine.

The productivity increase of the machine for picking cotton, an increase in yield leads to quick filling of the basket with cotton, and a driver has to manually ram cotton in the basket in order to reach the headland to unload cotton into a transport cart [14]. This takes additional time.
The increase in geometric dimensions of the basket is limited by strength of the structure and transport dimensions.

Compaction of cotton was considered by A. Khadzhiev, L.M. Kurtsenko [15], V.M. Golovin [16], A.Y. Yampolskiy [17], P.V. Baydyuk [18], U. Azizkhodzhayev [19], V.A. Fyodorov [20], Sh.V. Israilov [21]. However, an efficient technology and design of a compactor for compacting cotton in a hopper have not been developed. The mentioned studies are devoted to the processes of pressing cotton fibers into bales in molds and tamping raw cotton in transportation vehicles.

The peculiarities of compaction of raw cotton in the basket of a cotton picking machine are large volumes where compaction occurs, a significant volume of air in the cotton mass and its large pubescence, presence of litter and green leaves, need to compact cotton during the cotton harvest. Taking these features into account, the main requirements for the process of compaction of raw cotton in the basket of a cotton picker have been formulated:

- uniform, layer-by-layer compaction without stopping the machine;
- unimpeded separation of litter from the cotton mass, excluding the risk of injury caused to seeds and fibers, as well as its staining with the juice of green leaves;
- unhindered loading of a basket with raw cotton and its unloading into a transport cart;
- quick installation and dismantling of a compactor.

2. Materials and Methods

To increase the productivity of a cotton picker and to eliminate manual ramming of raw cotton in the hopper, a paddle compactor has been developed, design of which is shown in figure 1.

![Figure 1](image1.png)

**Figure 1.** Structural diagram of the cotton compactor in the basket

Basket 1 with a loading nozzle 2 contains a blade 3, which is movably connected to the swinging stands 5 and 6, hinged to the bottom of the basket. A lever 7 is rigidly connected to the blade 3, shoulders of which are connected to the bottom of the basket through the rods 8 .. 9. Supports 5 and 6 are fixed to the bottom of the basket by means of a special frame 10. The compactor is driven by a hydraulic cylinder 11.
When the supports 5 and 6 move backward or forward, the drag bars 8 and 9 alternately tighten and turn the blade relative to the stands at the certain angle along the direction of the machine, creating additional pressure on cotton.

The technology of loading cotton into the basket causes initial accumulation of the cotton mass in its rear part. This leads to the need to influence the cotton in this area with great effort. As the basket is filled with cotton, a local layer-by-layer compaction of the cotton is achieved by cyclical action on the cotton with a tightening paddle, which increases the efficiency of the compaction process.

3. Results and Discussion
The issue of increasing the capacity of a basket during the operation of a combined cotton picker, which has replaceable harvesting devices, is particularly acute. In the horizontal spindle design, the machine harvests cotton in one pass with increased productivity.

With the transition to a one-time cotton picking, the amount of cotton collected in the basket has increased, especially when a combined cotton picker with horizontal spindle devices is operating. There was a need to harmonize the basket capacity and the run length. With a long run, as noted above, one has to stop the machine and manually tamp the cotton in the basket to increase the capacity. It is irrational to reduce the run length, because a significant portion of the crop is lost at each headland.

A combined cotton picker with horizontal spindle devices with a cotton yield of \( Q = 40 \) c/ha in a two-row version with a working width of \( B = 1.8 \) m at a working speed of \( V = 5.05 \) km/h will have a productivity equal to 0.96 kg/s.

With the volume of the basket \( W = 14.7 \text{ m}^3 \) and specific gravity of the bulk raw cotton \( \gamma_c = 50 \text{ kg/m}^3 \), the machine will collect a full basket (727.7 kg) when:

\[
t = \frac{360 \cdot W \gamma_c}{QBV_2}.
\]

Substituting the indicated parameters into formula (1), we obtain \( t = 12.7 \) min.

The same machine with vertical-spindle devices in one pass (at the first harvest \( V_1 = 3.75 \) km/h) will collect a full cotton basket in 19.2 minutes and with the fractional harvesting technology [22] at the second speed (\( V_2 = 5.05 \) km/h) travelling by car in 24.5 min.

A cotton picker with horizontal spindle devices at a second working speed for collecting a full basket will pass the way:

\[ S = Vt = 1066 \text{ m}. \]

If the headland is longer, a driver will have to stop the machine and manually ram the cotton in the basket.

![Dependence of the run length on the cotton mass in the basket](image-url)
Figure 2 shows the required length of furrow depending on the weight of the harvested cotton in the cotton picker basket. (1 - horizontal spindle collection without the compactor, 2 - the same with the compactor, 3 - fractional collection, 4 – first vertical spindle collection)

With a fractional collection, a machine with vertical-spindle devices will collect a full basket on a run of 1650 m, and when using a track-in-track technology [23], at the first collection - 1150 m.

When the density of cotton in the basket reaches 80 kg/m$^3$, the weight of cotton reaches 1176 kg and the machine will travel 1680 m. If there is a compactor, the machine will pass this section of the field without stopping. This means that for a combined cotton picker, the length of the run can be increased to 1600-1700 m. The machine will travel this path in 20 minutes, which will increase the productivity of cotton picking.

The compactor begins to effectively compact cotton when there is $W_u = 400$ kg of loose cotton in the basket.

Using formula (1), we find that it takes 6.6 minutes to harvest 400 kg of cotton. This means that 6.6 minutes after the start of the machine, it is necessary to turn on the compactor.

If 1176 kg of compacted cotton is collected in 20 minutes, then during the period of the operation of the compactor, $1176-400 = 776$ kg of cotton will be collected in $20-6.6 = 13.4$ minutes.

The average compaction cycle time ($t_n = 3.73$ sec) was experimentally established. During this time, 3.6 kg of cotton will enter the basket.

Let us take the time interval for turning the compactor into operation $t_c = 2.0$ minutes. During this time, 115 kg of cotton will enter the basket. Then the number of intervals when the compactor is switched on in order to achieve a cotton density in the basket of 80 kg/m$^3$ (1176 kg) will be:

$$ K = \frac{W_u}{\gamma_u \cdot \gamma_c} $$

Making calculations, we get:

$$ K = 7. $$

In this case, a compaction coefficient:

$$ K_n = \frac{\gamma_u}{\gamma_c} $$

where: $\gamma_u$ – density of compacted cotton, $\gamma_c$ – density of bulk cotton in the basket.

Let us assume that after each interval when the compactor is switched on, the blade performs three compaction cycles. Then, for 7 intervals (switching on) of work, the compactor will perform $n = 21$ compaction cycles.

The work done in one compaction cycle will be equal to:

$$ A_{hl} = P_h S_h $$

provided that:

$$ P_l = P_h \frac{S_h}{h_l} $$

where:

$P_h$ – hydraulic cylinder force;

$P_l$ – force on cotton layer;

$S_h$ – hydraulic cylinder stroke;

$h_l$ – elastic deformation of a cotton layer.

For the cycle of operation of the compactor, we take the total time of movement of the blade from the extreme rear to the extreme forward position and back.

If the force on a hydraulic cylinder rod is 4 kN, the stroke of the rod is 0.2 m, then the average work in one compaction cycle will be equal to:

$$ A_{hl} = 0.8 \text{ kNm}.$$ 

The total work performed by the compactor will be equal to:

$$ A_n = A_{hl} / n = 16.8 \text{ kNm}.$$
The whole compacting process will take:

\[ t_o = t_s \Pi_s = 78.33 \text{ sec.} \]

Then the power required for operation of the compactor will be equal to:

\[ N = \frac{\Pi_s}{t_o} = 0.22 \text{ kW}. \]

Thus, the following parameters can be recommended for designing a cotton compactor in the basket of a combined cotton picker:

- hydraulic cylinder TsS-55 with a working stroke of 200 mm;
- interval between switching on the compactor into operation is 2 minutes;
- number of compaction cycles - 3;
- number of intervals - 7;
- compaction cycle time - 3.73 sec;
- number of compaction effects of the blade on cotton \( \Pi_s = 21 \);
- basket volume - 14.7 m\(^3\);
- maximum run length is 1600-1700 m.

The first switching on of the compactor into operation is 6-7 minutes after arrival in the field. Field trials of a combined cotton picker have shown that the paddle compactor does not degrade quality of the harvested cotton (clogging, seed breakage, injury and fiber greening).

4. Conclusions

Use of a paddle compactor in the combined cotton picker made it possible to efficiently distribute the cotton mass throughout the basket. The local layer-by-layer compaction of cotton increased the basket capacity 1.4-1.6 times, eliminated manual ramming of cotton, reduced the travel time and the amount of unloaded cotton into transport carts. The cotton picking productivity increased by 10-15% while maintaining its quality.

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