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Investigation of The Technological Process of Work and Justification of the Parameters of Raw Cotton

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Abstract. The article substantiates the method of compaction and the parameters of the compactor of raw cotton in an elastic container, which make it possible to increase the productivity of cotton pickers due to the large capacity of the container and the increase in the coefficient of use of shift time. A layered compaction method has been studied, which makes it possible to compact the cotton mass with its continuous flow from the bottom to the neck of the container. Theoretically, the pressure in various layers of the cotton mass, the distance between the inner ends of the sealing elements, the magnitude of the stroke and the speed of movement of the sealer, the volume of the container are determined, the coefficients are found that take into account the elongation of the height of the container and the layering of the seal. All parameters are substantiated from the condition of ensuring high productivity and reliability of the cotton pickers.
Keywords: field, container, compactor, layer-by-layer compaction, layering coefficient, elastic, relaxation, locking device.

1 Introduction

In the production of raw cotton, one of the labor-intensive operations is harvesting and transporting the crop [1-2]. At present, cotton harvesters harvest a significant part of the crop to increase the level of mechanization of harvesting and transporting raw cotton, the productivity of harvesting and transport machines is of primary importance [3]. The use of raw cotton compactors in bunkers leads to an increase in the productivity of harvesters by 10-15%. At the same time, the carrying capacity of vehicles is not fully used [4-9].

The new technology is schematically as follows: "field - container - loader - transport trains - procurement station" [10-11]. The cotton picker must have a magazine for empty containers in a quantity that ensures uninterrupted operation of the machine during a shift or half-shift, reserving capacities necessary to store filled containers until the machine leaves the field for the headland [12].

The compaction of raw cotton in a container using a new harvesting and transportation technology is essential, since the productivity of cotton pickers depends on the capacity of the container. Therefore, the solution of issues related to the mechanization of the compaction of raw cotton in a container is an urgent task to increase the productivity of cotton pickers,

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further increase the mechanization of work in cotton growing and improve the working conditions of workers involved in the harvesting and transportation of raw cotton [13].

When harvesting, raw cotton is reloaded from the bins of harvesters into vehicles at the edge of the field free from plants, since vehicles entering the field cause damage to plants and lead to large losses of cotton. Therefore, before the start of machine harvesting at the beginning and end of the cotton field, strips 8–10 meters wide are prepared for turning the cotton pickers and placing vehicles to receive the harvested cotton from the cotton picker bunker [14-15].

The box capacity of the cotton picker can hold about 800 kg of machine-picked bulk cotton. In order to effectively use the volume of the body, the cotton in the trailer is rammed with feet. At the same time, the mass of raw cotton in the trailer is 1700 ... 2000 kg, while its nominal load capacity is 4 tons and it is not used by about half. Tractor trains, after being filled with cotton, are sent to procurement centers [16].

Analyzing the above, it should be noted that the existing method of harvesting and transportation has a number of significant drawbacks and does not meet the requirements for increasing the production of raw cotton. A promising solution to this issue is the use of containers for harvesting, loading and unloading and transportation of raw cotton [17-22].

2 Materials and methods

Theoretical studies have determined a factor that takes into account the density of the seal, a factor that takes into account the elongation of the container, the stroke of the seal, the speed of movement of the seal up and the distance between the sealing elements [23].

It was supposed to use these parameters of the compactor to provide the highest density of raw cotton in the container at lower energy costs. This position required experimental confirmation. Considering the above and in accordance with the task set, the following works were included in the experimental research program:

1. Experimental studies of the parameters of the sealant in the laboratory, including the determination of:

– determination of the best compaction method and compactor scheme;

– determination of the number and section of sealing elements and sealing force;

– study of the layer-by-layer method of compaction;

– determination of the layering coefficient;

2. Experimental studies of the parameters of the compactor in the field, including:

– study of the layer-by-layer method of compaction in order to increase the density of raw cotton;

– study of the influence of the main parameters of the compaction, in order to increase the performance of the compactor and cotton raspberries;

– comparative studies of a cotton picker equipped with a raw cotton compactor in an elastic container and a serial cotton picker in terms of agrotechnical indicators and stability [24].

Various designs of seals were experimentally investigated, the process of sealing, the properties of cotton during compaction were investigated, and a requirement was made for the designs of cotton seals in a container [25-26].

Then the shortcomings were taken into account and, on the basis of theoretical proposals, the final requirements for the design of seals were determined. They come down to this:

1. The compactor must work from top to bottom.

2. Compaction should occur in layers as the cotton is filled from the bottom to the neck of the container.

3. Compaction should be carried out with the least energy consumption.

4. The compactor must provide a cotton density of 160-180 kg/m3.

5. The capacity of the compactor must be greater than the mass input in a two-row machine.
6. Sealing elements must seal the mass around the periphery of the container.
7. Sealing elements should not interfere with the distribution of cotton in the container.
8. The seal must be non-metallic and reliable in operation.
9. The dimensions of the seal must allow placement in a container [27].

To determine the best compactor scheme, we developed and manufactured a laboratory installation for studying the process of compacting raw cotton in a container (fig. 1).

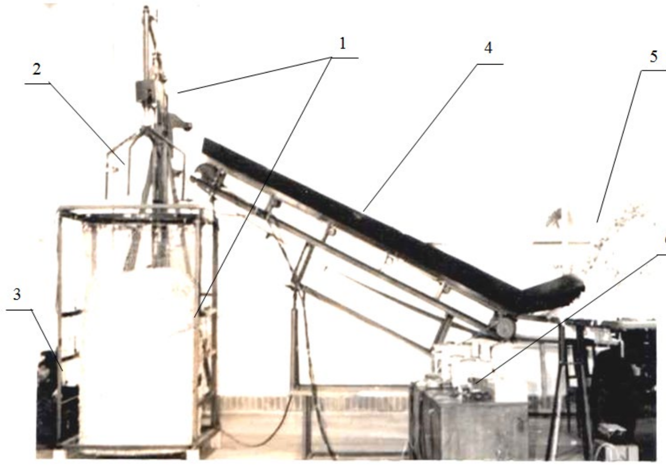

Fig. 1. Laboratory installation for the study of the process of compaction of raw cotton in a container.

1 - sealant with a container; 2 - sealing element; 3 - pumping unit; 4 - inclined conveyor; 5 - trailer with cotton; 6 - strain gauge console.

It works in the following way. Cotton from the trailer 5 is fed in certain portions to the inclined conveyor 4, which has a belt speed of 0.7 m/s. The sealer, which is at this moment at the bottom of the container, begins to compact the incoming cotton. Due to the inclined position of the conveyor and the rotary movement of the sealing elements, the incoming mass is distributed evenly over the entire area of the container [28-29].

The force from the hydraulic cylinder through the two-arm lever and the sealing rod is transmitted to the sealing elements. The hydraulic cylinder of the laboratory unit is driven by the hydraulic system pump 3.

Thanks to the holding mechanism installed in the rod, the sealing elements are able to apply the sealing force to the cotton for some time. The holding mechanism is shown schematically in fig. eight.

The shutter speed of the distributor switch lever 8 is obtained by compressing the springs. When the lever is in the upper position, the upper spring 6 is compressed. The springs are compressed due to the fact that the distance between the upper and lower positions of the flywheel is greater than the distance between the upper and lower positions of the shift lever.

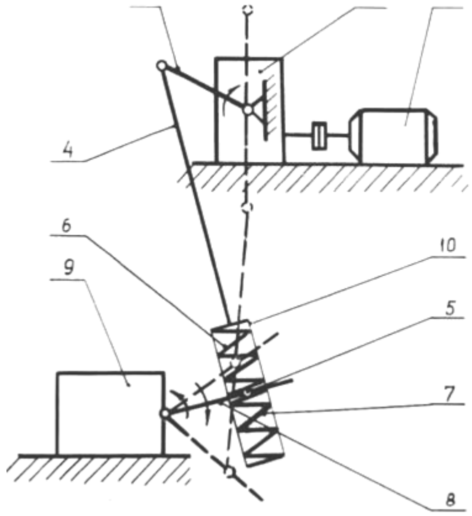

Fig. 2. Scheme of automatic switching of the hydraulic distributor lever.

1-electric motor; 2-reducer; 3-flywheel; 4-thrust; 5-roller (rigidly installed on the shift lever 8 and freely installed in the guide groove); 6-upper compression spring; 7-lower compression spring; 8-distributor switching lever; 9-hydraulic distributor; 10-guide groove.

A cylindrical mesh container was made for the experiments. Container options:
diameter $Dk = 1.1$ *m*,
height $Hk = 1400$ *mm*
cell sizes diagonally (75 × 50; 40 × 25 *mm*).
Mesh container material feature:
Product name - fishing line TU. 221.2-75.
Variety - 1
Cross section d = 2,3 *mm*.
Tensile load characteristic - P = 0.8 *kN*.
The scheme of the claw type seal is shown in fig. 3.

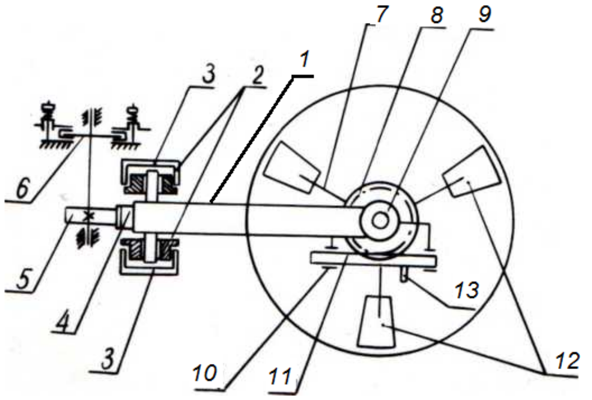

Fig. 3. Scheme of a pawl-type seal.

1-cantilever beam; 2-rollers; 3-vertical guides; 4-rail; 5-tooth wheel; 6-friction clutch; 7-sylinder on the ruler; 8-stem seal; 9-star bracket; 10-arm lever; 11-power cylinder; 12 sealing elements-paws -; 13-rail of the rotary mechanism.

The claw type seal works as follows. A cantilever beam with a star bracket is lowered to the bottom of the container. The friction clutch must be adjusted to a force that provides the required seal. When the power cylinder rod reaches the top point, the force is transmitted through the two-arm lever 10, the rod, the star-shaped bracket to the sealing elements.

When the power cylinder rod reaches the top point, the force is transmitted through the two-arm lever 10, the rod, the star-shaped bracket to the sealing elements. rises up. At this time, the guide sleeve 26 acts on the stop 27 and raises the rod 23, which turns the two-arm lever 24, and it sets the rack 13 in motion. The gear wheel 15, rotating, turns the ratchet 17 and the bracket 19. The latter transmits rotation of the star bracket, i.e. to sealing elements [30-31].

Thus, the sealing elements at the end of each cycle take a new position. At the same time, the displacement of the subsequent place of application of the sector-type sealing elements relative to the previous one is selected with some overlap.

Due to this, the compaction is more efficient, because. carried out at high specific pressures. The lower stop 28 serves to return and the initial position of the two-arm lever 24.

With the flow of cotton mass under the sealing elements, the cotton density increases and the force of resistance to compaction increases, which is transmitted to the friction clutch through the star-shaped bracket and rod, two-arm lever 10, cantilever beam I, rack 4 and gear wheel 5. When the seal rises, the ratchet 31, due to the compression of the spring, passes it up, and during the replacement of a full container with an empty one, under the action of the spring, wedging into the teeth of the rack 4, fixes it in this position. After replacing the container through the rod 33, the ratchet releases the rail, and the cantilever beam smoothly goes down. The sealing elements reach the bottom of the container and the whole process is repeated [32].

During the experiments, the following parameters remain constant:

– number of paws, *n,*

– paw dimensions, s, sm^2,

– angle of rotation of the sealing elements, α, *degrees*,

– seal stroke, h_u, m.

Initially, experiments were carried out with the usual method of compaction. The sealing elements are constantly above the container in the upper position. First, the container is filled with loose cotton up to the neck. This is followed by compaction. Varies sealing force.

$$P = 1\ kN,\ 1.4\ kN,\ 1.8\ kN,\ 2.2\ kN,\ 2.6\ kN.$$

After these experiments, layer-by-layer compaction is carried out under the same conditions. In this case, only the sealing starts from the bottom and as it is filled up to the neck of the container. All experiments are carried out three times.

After the experiments, the following quantities are determined:

– mass of cotton in a container, *G, kg,*

– container filling time, *Tk, s,*

– density of cotton, γ, kg/m^3.

The ratio of the density of cotton in the layer-by-layer method of compaction to the density in the conventional method gives the coefficient of layer-by-layer compaction of raw cotton - *Kp*.

3 Results and discussion

Piston seals, although simple in design, but, as experiments have shown, have a number of significant drawbacks. The zone of action of the sealing force during their operation is limited, namely, the seal occurs only in the area of the exit from the piston chamber. The increase in cotton mass in the container leads to a sharp increase in the force required for compaction. The friction between the cotton and the chamber wall also increases its value.

In addition, the density indicators are low. Therefore, with a compaction force P = 0.45 ... 0.5 *kN*, the density of cotton in the container is γ = 140 ... 150 kg/m^3.

Although screw compactors ensure the continuity of the process, their work is associated with fiber rupture, clogging of cotton, and damage to seeds. The outlet feather of the auger is constantly in the container with the compacted mass, which also leads to an increase in energy consumption for compaction and a decrease in density, since the compacted mass is constantly loosened by the feather.

Therefore, with a compaction force on the shaft P = 0.5 - 0.6 *kN*, the density of cotton in the container was obtained no more than, γ = 130 - 140 kg / m^3. The roller seal, despite the simplicity of the design, has a number of significant drawbacks. During compaction, due to the small area of contact with the cotton, the rollers sink into the cotton mass. Therefore, the performance of the seal deteriorates and low density values are obtained [28]. With a compaction force P = 0.4 - 0.5 *kN*, the density of cotton in the container was obtained not higher than γ = 70 - 80 kg/m^3.

The claw seal achieves density values with lower energy consumption. This is due to the fact that they are compacted in layers with the incoming portion of cotton and because of the high values of the specific pressure on the cotton. In experiments with a pawl compactor with a compaction force P = 0.4 - 0.5 *kN*, the cotton density in the container was obtained γ = 160 - 170 kg/m^3.

In the future, we had to create a natural-sized compactor that works on a cotton picker when harvesting raw cotton. For this purpose, a laboratory setup was made. At the installation, a pawl seal with sector-shaped sealing elements was investigated [29].

The results of the experiments are shown in table 1;

The disadvantage of this compactor is that it takes a large number of cycles for compaction.

The significant advantages of this design allow it to be preferred.

In this regard, further studies were carried out to determine some parameters of the claw type seal. The following parameters have been studied:

– number of sealing elements;

is the angle of rotation after each compaction cycle;

– compaction force;

– the course of the seal;

– distance between sealing elements;

– the speed of movement of the sealing elements.

Table 1. Results of experiments with the claw seal

Sealing force	Quantity seal elements	Cross-sectional area	Container height	Container volume	Cotton weight	Cotton density	Filling time	Productivity	Angle of rotation	Pressure on cotton
P	***n***	***S***	H_K	V_K	G_X	γ	***T***	W_y	φ	***P***
kN	pcs	sm^2	***m***	m^3	***kg***	kg/m^3	***s***	***kg/s***	deg	***kPa***
1,2	3	200	1,6	1,5	225	150	480	0,47	55÷60	2,0
1,2	4	200	1,6	1,5	220	146	420	0,52	40÷45	1,5
1,2	3	200	1,6	1,5	220	146	480	0,45	55÷60	12
1,2	4	200	1,6	1,5	218	144	420	0,51	40÷45	10

The results of experiments to determine the value of the angle of rotation of the sealing elements are shown in table 2.

Table 2. Values for the rotation angles of the star seal.

Number of legs	Cross section of legs			
	1	**2**	**3**	**4**
№ 1	15	20	25	15
№ 2	20	40	40	20
№ 3	30	50	45	30
№ 4	40	60	75	40
№ 5	50	80	90	45
№ 6	60	90		60
	27 … 30°	147 … 50°	40 … 45°	35 … 40°

The optimal angles of rotation of the star-shaped bracket are determined before carrying out experiments to determine the remaining parameters of the seal. At optimal values of the angle of rotation, the best performance was obtained [33].

1. Based on the study of literary sources, the layer-by-layer compaction method is theoretically substantiated. A coefficient has been introduced that takes into account the layer-by-layer compaction method. Experimental studies have proven this compaction method and show that it increases with increasing compaction force and cotton moisture content. The sealing method is protected by copyright certificates № 931127, № 1039456 [25; 34].

2. In the formula for determining the pressure in the lower layer, a coefficient is introduced that takes into account the elongation of the height of the container and its numerical value is determined K_R = 1.1 - 1.21 with a compaction force P = 1 (1.0-2.0) *kN*.

3. It was found that an increase in the stroke of the seal leads to an improvement in the performance of the seal. The best value is hy = 0.4 *m*.

4. Changes in the compaction rate from the density of cotton have been studied and it has been proven that they are disproportionate.

5. Experimental studies substantiated the distance between the sealing elements, which is equal to Ly = 0,55-0,65 *m*.

6. Experimental studies have studied various schemes of seals and a claw-type seal has been selected. The best parameter values are:

– number of sealing elements, P = 4 *pcs*;

- angle of rotation of the sealing elements, $\alpha = 42 - 45^{o}$ *degrees*;

- dimensions of sealing elements, S = 250 - 300 sm^2;

– compactor stroke, hy = 0.4 *m*;

– compaction force, P = 2.0 - 2.2 *kN*.

7. Theoretically, the volume of the container is determined, which is equal to: Vk =1,8-2,2 m^3.

Container options:

- container diameter, Dk = 1,1 - 1,2 *m*;

– container height, Hk = 1,9 – 2,1 *m*.

8. The cotton picker, equipped with a containerized raw cotton compactor, improves the productivity of the machine by up to 24 % [34].

4 Conclusions

1. In the production of raw cotton, the most promising method is containerization.
2. In this technology, the main role is played by a cotton picker equipped with a layered compactor.
3. Further work should be carried out in the direction of studying the operation of the compactor on multi-row cotton pickers.
4. Refine some mechanisms to fully automate the actions of all systems.

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