
CONFERENCE ARTICLE

Theoretical Substantiation Of The Dynamics Of Interaction Between The Fiber Bundle And Saw Teeth

I. Z. Abbazov

DSc, Jizzakh Polytechnic Institute, Jizzakh, Uzbekistan

O. N. Alimov

PhD, Jizzakh Polytechnic Institute, Uzbekistan

B.N. Sharopov

Independent researcher, Jizzakh Polytechnic Institute, Jizzakh, Uzbekistan

J.X. Abdurasulov

Database Manager, Department of Registrar Office, Jizzakh Branch of the National University of Uzbekistan named after Mirzo Ulugbek, Jizzakh, Uzbekistan

Abstract: The article presents the analyzes of the gin equipment used in cotton ginning enterprises, the theoretical solutions of the construction proposed to eliminate them and their shortcomings are presented. The main advantage of the proposed construction is that the elastic element does not tightly clamp the fibers, but by holding them for a short time, ensures that they move to the next saw tooth. This ensures reliable grip of the fiber and increases the stability of the technological process in the working chamber. As a result, the probability of fiber sticking to the saw teeth increases, the premature removal of fibers from the tooth decreases, the efficiency of separating the fiber from the seed increases, the quality of the fiber improves, and the overall stability and reliability of the ginning process is ensured.

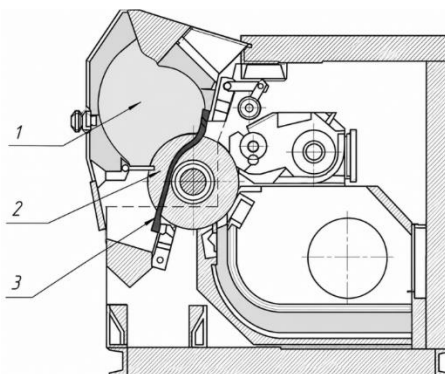
Keywords: Cotton, fiber, gin, structure, saw, dynamics, normal force, tangential force.

INTRODUCTION

Until the 1980s, cotton ginning plants used 80-row 3XDD, then 86-row 3XDDDM gins [1]. In a single-battery cotton ginning plant, 4-row gins were installed in the technological system to produce the required amount of fiber according to the technological regulations. The large number of gins in the technology led to high operating costs and electricity consumption [2].

In order to reduce costs and increase the productivity of the enterprise, by 1980, the DP-130 model with 130 saws was first

developed, and then this machine was improved and produced in the 4DP-130 and 5DP-130 models and widely introduced into production (Fig. 1) [3, 4]. These gins were made due to the increase in the number of saws on the shaft and the increase in the size of the gin. The chain saw cylinder consists of 130 saw blades and 129 saw blade spacers. The diameter of the place where the saws are assembled is 100 mm, the length is 2240 mm, and the weight is 161.4 kg [5].



1- working chamber, 2- saw cylinder, 3- colosnik grid

Figure 1. Schematic diagram of the 4DP-130 chainsaw

The gins with a single or double chamber, depending on the number of working chambers. In a double-chamber gin, there is a feeder that feeds cotton into the working chamber in one plane and an additional cleaning chamber. The cleaning chamber (section) additionally cleans the cotton with the help of a drum with a pick. However, this negatively affects the gin productivity, i.e. the cleaning chamber limits the passage of cotton through the gaps in the gin and the comb.

The increase in the productivity of the gin with a single chamber leads to an increase in the quality of the cotton collected from the working chamber. To reduce the grain breakage, when the number of rollers is increased from 80 to 90 without changing the length of the roller cylinder, the distance between the rollers is reduced from 19.40 to 16.35 mm, which in turn leads to a decrease in the exit of the broken grains from the working chamber and an increase in the number of short fibers.

The analysis showed that achieving high efficiency while maintaining the quality indicators of fiber and grain in saw mills mainly depends on the design and technological parameters of the working chamber, saw cylinder and grate. In existing mills, the unstable rotation of the raw material shaft, the unevenness

of the saw teeth during the fiber pick-up process, the interaction with the grates and the resistance to removing the fiber from the saw teeth have a negative impact on product quality and process efficiency. Although increasing the number of saws and the dimensions of the working chamber can increase productivity, it can lead to an increase in the number of fibers, short fibers, and technological defects. Therefore, it is important to improve the design solutions that ensure reliable fiber capture by the saw teeth, its stable transport between the coulters, and effective removal from the teeth. In this case, coordinating the interaction of the saw cylinder with the movement of the raw material in the working chamber is one of the main directions for reducing fiber damage and increasing the stability of the collection. From this point of view, there is a need to analyze the existing domestic research and development work on increasing the efficiency of the processes of saw fiber separation and removal of cotton fiber from the saw teeth. In most theoretical studies, it is emphasized that the greater the number of fibers caught on one tooth, the higher the efficiency. Considering that all the parameters of the process depend on the number of fibers caught in one sawtooth, we will improve the inner chamber of the gin in the following way (Figure 4).

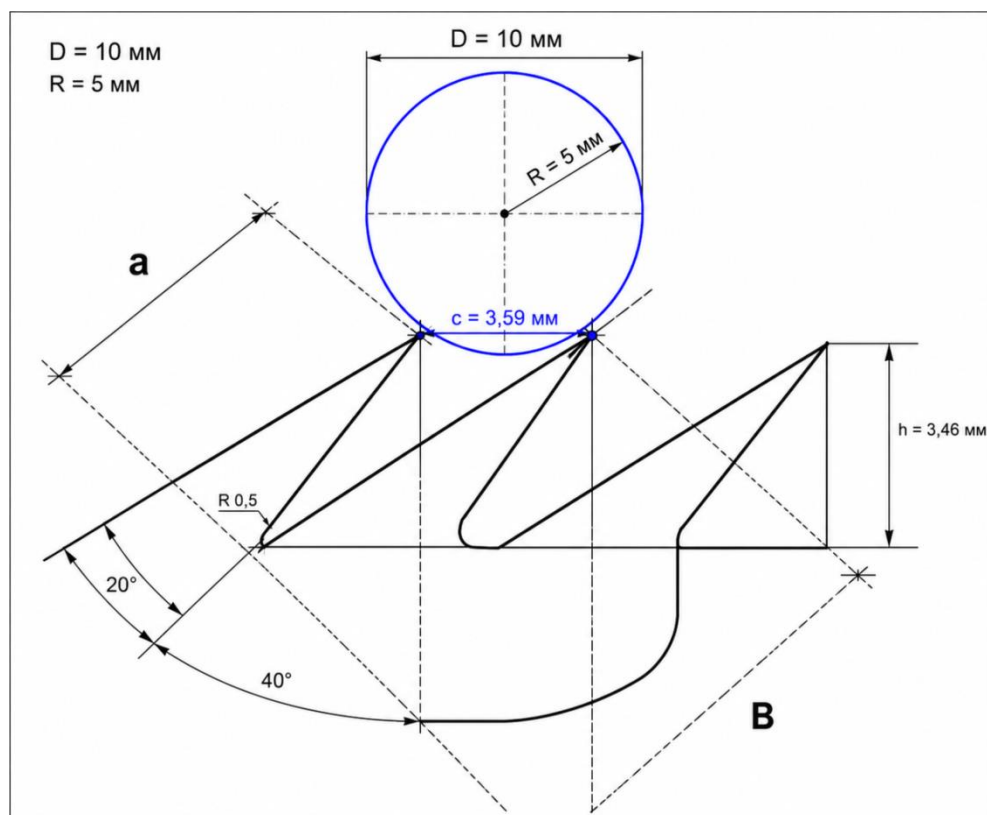


Figure 4. Improved working chamber elements with elastic element installed

The design shown in the figure shows an elastic element that holds the fibers. The principle of operation of this design is as follows.

As a result of the rotation of the saw cylinder, the cotton seed is caught in the saw teeth and moves inside the working chamber. The fibers caught in the saw teeth can usually be separated from the teeth under the influence of centrifugal force, air flow and vibrations. In the proposed design, the bundle of fibers caught in the saw tooth comes into light contact with the elastic element located in the upper part of the working chamber.

The elastic element holds the bundle of fibers for a certain time and prevents it from leaving the saw tooth. During this time, the next rotating saw tooth also has the opportunity to catch on these fibers. As a result, one bundle of fibers is simultaneously caught by two neighboring saw teeth, and its movement is stabilized.

The division of fibers into two saw teeth ensures a uniform arrangement of fibers in the working chamber, reduces fiber

slippage, and makes the process of separating fibers from the sawdust more efficient. At the same time, the likelihood of excessive tension and mechanical damage to the fibers decreases.

The main advantage of the proposed design is that the elastic element does not compress the fibers tightly, but rather holds them for a short time, ensuring their transfer to the next saw tooth. This ensures reliable fiber retention and increases the stability of the technological process in the working chamber.

As a result: the likelihood of fibers sticking to the saw teeth increases, premature fiber departure from the tooth decreases, the efficiency of separating fibers from the sawdust increases, fiber quality improves, and the overall stability and reliability of the sawing process is ensured.

Determination of normal and tangential forces acting on the fiber. If the normal stress distribution along the contact zone is known, the total normal action of the elastic element on the fiber

bundle:

$$N_e = b_e \int_0^{L_k} q_n(x) dx \quad (1)$$

Tangential effect:

$$T_e = b_e \int_0^{L_k} q_t(x) dx \quad (2)$$

If, to a first approximation, the stress is assumed to be uniformly distributed along the contact zone,:

$$N_e = q_n b_e L_k \quad (3)$$

$$T_e = q_t b_e L_k \quad (4)$$

When the Coulon friction law is adopted between the fiber and the element:

$$T_e \leq \mu_e N_e \quad (5)$$

and in the case of limit slip:

$$T_e = \mu_e N_e \quad (6)$$

here μ_e - coefficient of friction between the cotton fiber and the surface of the elastic element.

This indicates that the fiber-gripping capacity of the elastic element depends not only on its stiffness but also on its surface characteristics. With a very smooth element, the gripping force is low, potentially allowing the fiber to slip, whereas excessive friction can cause the fiber to become over-tensioned. Therefore, the material and surface condition of the element must be treated as distinct factors in future experimental studies.

Graphical analysis shows that the normal force N_e acting on the fiber bundle increases linearly with increasing deformation of the elastic element. In a soft element ($k_e=12$ N/mm) with mm, the normal force is approximately 18 N, in the base case ($k_e=20$ N/mm) it is 31 N, and in a rigid element ($k_e=30$ N/mm) it reaches 49–50 N. Thus, an increase in the element stiffness significantly increases the contact force acting on the fiber at the same deformation.

An element of moderate stiffness is considered preferable, as it ensures the fiber is securely held by the saw teeth without subjecting it to excessive mechanical stress. Specifically, with values of $k_e \approx 20$ N/mm and mm, the graph indicates a force of $N_e \approx 10$ N; this point can be adopted as the optimal calculated operating mode for subsequent experimental studies.

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