

Investigation of the process of the influence of winding spindles with cotton fiber on the performance of a cotton picker

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Abstract. One of the factors affecting the performance of a cotton picker is the process of winding the spindles with cotton fiber. Therefore, studying the effect of the process of winding spindles with cotton fiber is one of the important problems. Based on the conducted research, the influence of the process of winding spindles with cotton fiber really affects the performance of the cotton picker.

1 Introduction

The process of extracting a piece of cotton from the box is accompanied by the capture and subsequent winding of it on the spindle. When winding, the slice lengthens from the minimum value at the initial moment to the maximum value at the moment of extraction. The cotton wound on the spindle will be removed from the spindles in the removal area with the help of strippers and self-resetting due to the reverse of the working body.

During the removal process, depending on the winding force and the moisture content of the cotton cloves, part of the fiber, breaking away from the main mass, may remain on the spindle and thereby form a winding. This phenomenon mainly occurs at high moisture content of raw cotton. In addition, windings can also be formed due to the fiber catching on the protruding burrs present on the surface of the spindles.

Increasing the productivity of cotton-picking machines is carried out in two ways: by increasing agrotechnical indicators and the stability of their operation.

The stability of the technological process of a cotton picker depends on the geometric, speed, technological and dynamic parameters of the machine, the physical and mechanical properties and yield of raw cotton, the quality of defoliation of cotton, the condition (presence of weeds) and topography of the fields, as well as the qualifications of the driver.

Given the current geometric and speed parameters of cotton harvesters, the stability of the technological process largely depends on the quality of manufacturing, design, frequency of cleaning and washing the spindles from green mass, the stability of technological adjustments, the yield of raw cotton, the degree of opening of bolls, the quality of defoliation of cotton and the degree of weed removal vegetation.

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One of the main reasons for the decrease in the completeness of cotton collection into the hopper as the machine operates is the greening and wrapping of their working parts - spindles - with cotton fiber. To reduce the greening of spindles and increase the stability of machine operation, cleaners, puller-cleaners, spindle humidifiers, polymer coatings, composite spindles, etc. have been created.

The serial vertical spindle is a rod with four milled valleys and teeth with a diameter of 24 mm and a working surface length of 615 mm. The main disadvantage of these spindles is the low capacity of the teeth, due to which the spindle quickly turns green and loses its cotton picking ability.

Improving serial working bodies (spindles) by changing their geometric and speed parameters increases the agrotechnical performance of cotton harvesting machines. However, their stability remains at the same level. Further improvement, aimed at increasing stability and simplifying the design of the spindles, followed the creation of working bodies consisting of two elements - a rod and a gripping element [1].

2 Materials and methods

After machining the surfaces of metals by any method, there are always micro burrs. When they come into contact with raw cotton, sliding friction occurs between them. In the presence of micro burrs exceeding the thickness (0.005-0.02 mm) of cotton fibers 5-10 times, the fibers either get caught in them [2, 3], or are destroyed. In the first case, the fibers gradually accumulate and form a ring-shaped winding in serial spindles or a screw-shaped winding in screw compound spindles. In some cases, these windings are automatically removed by pullers in the pull-off area. The occurrence of windings due to micro deburring, compared to the first case, is very rare because after machining the spindle surface, electro polishing and chromium plating are performed to remove the micro deburring. In this with connection, windings appearing due to high moisture content of raw cotton were investigated. When moistened, the cotton fiber loses its elasticity and becomes very flexible. During the winding process, depending on the strength of the tension, the cotton lob sticks to the surface of the spindle cotton-gripping ability in the areas where the winding has occurred. The higher the moisture content of the cotton fiber, the more winding occurs on the spindles.

Studies [4, 5] found that the winding of spindles with cotton fiber mainly depends on the friction coefficient f , which, in turn, is determined by many factors: contact area, specific load, spindle speed, fiber moisture, and metal surface roughness. Among these factors, the winding ability is mainly affected by the moisture content of the fiber. The coefficient of friction changes the tension force of the flexible thread T . With a change in the moisture content of the cotton fiber, its tenacity changes, which characterizes the initial gripping force T_0 . In addition, according to the Euler formula $T = T_0 e^{f\alpha}$, the tension force of the flexible thread on the circle depends on f and α .

Let us consider the influence of the coefficient of friction and the moisture content of cotton fiber on the tension force T .

In [6, 7], the process of winding cotton on a spindle and removing it from the box using high-frequency filming is considered. On the basis of research, an analytical dependence was derived with respect to a rotating rough circle:

The fibers which are very strongly caught on the spindle surface separate from the bulk when uncoiled and remain on the spindle surface in the form of a ring. The spindle teeth lose their great force.

$$\frac{cT_0 e^{f\alpha(L_0 + \omega \cdot t)}}{S_{Sh}} + \frac{r}{f} \ln \frac{1 + cT_0 e^{f\alpha}}{1 + cT_0} - \omega \cdot t - \varphi_{Sh} \cdot r = 0 \quad (1)$$

$$\alpha = \omega \cdot t - 2 \arctg \frac{L_0 + \omega \cdot t}{1 + cT_0} \quad (2)$$

T_o – initial fibre tension force,
 L_o – initial thread length,
 α – the angle of wrapping the thread around the circle,
 $\omega \cdot t$ – drum rotation angle,
 c – the reciprocal of the tensile stiffness,
 φ_{Sh} – spindle rotation angle,
 r – spindle radius.

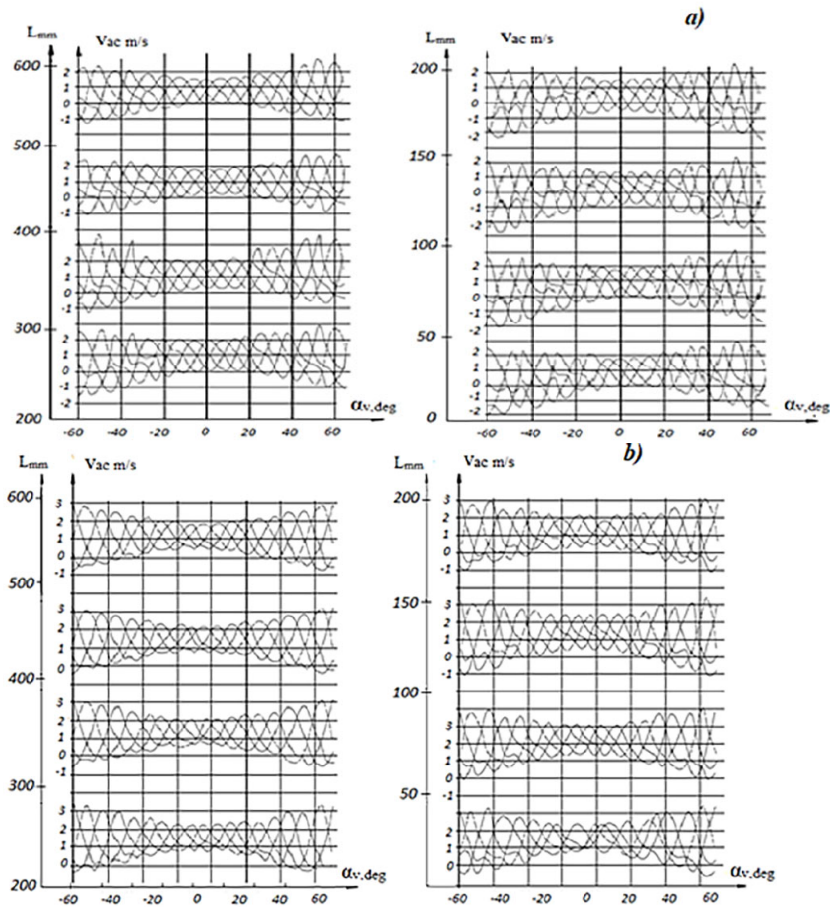


Fig. 1. The degree of activity of the teeth along the length of the spindles, depending on the greening: a) serial, b) screw compound spindle.

The solution of the problem according to formula (2) is very difficult. In [5, 10], a formula transformed on the $e^{f\alpha}$

$$T = \frac{1}{2L_o} \left[\omega \cdot t \cdot (1 + e^{f\alpha}) - \frac{r}{f} \cdot (1 - e^{f\alpha}) \cdot (L_o - \omega \cdot t) \right] \pm \sqrt{\left[-\omega \cdot t(1 + e^{f\alpha}) + \frac{r}{f} \cdot (1 - e^{f\alpha}) + e^{f\alpha}(L_o + \omega \cdot t) \right]^2 - 4L_o \left[\frac{r}{f} \cdot (1 - e^{f\alpha}) - \omega \cdot t \cdot e^{f\alpha} \right]} \quad (3)$$

3 Results and discussion

The value of the coefficient of friction, which depends on the moisture content of the cotton fiber, will be determined based on the results of laboratory studies of this work at a fiber moisture content of 5 to 25% (in the field, the moisture content of raw cotton usually does not exceed 25%).

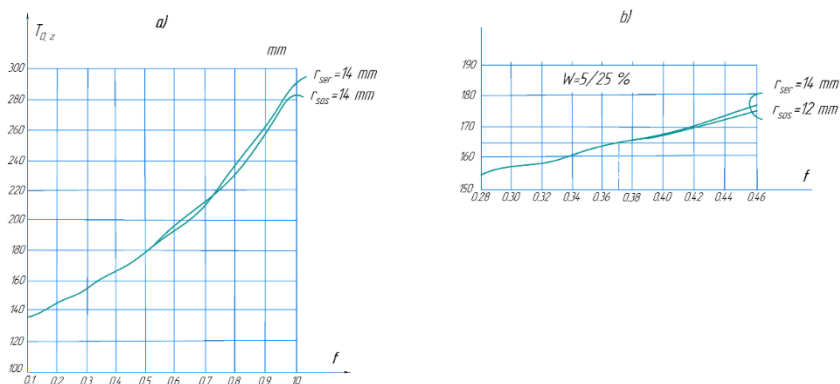


Fig. 2. Change of cotton fiber slices tension force depending on friction coefficient: a) for general case, b) depending on cotton fiber moisture content.

We accept the surface roughness of the spindle $R_z \sqrt[40]{f_{\text{max}}}$, the spindle speed is 1.6 m/s, the normal pressure is $P = 20 \text{ g}$.

Then the friction coefficient will be $f = 0.27 - 0.46$. Taking these values as a basis, we determine T for the mode of a 14X -2.4 cotton picker with serial and screw compound spindles, first at $f = 0 - 1.0$, and then at $f = 0.27 - 0.46$. Cotton variety 108-F. Required parameters: $r_{ser} = 12 \text{ mm}$, $r_{vin} = 14 \text{ mm}$, $r_b = 14 \text{ rpm}$, $\omega \cdot t = 40^\circ$, $\varphi_{Sh} = 40^\circ$, $L_o = 60 \text{ mm}$, $EF = 4.8 \text{ g}$, $V_m = 0,8 \frac{m}{s}$, $K = 1.58$;

$$t_{izvl} = 0,065 \text{ s then } \alpha = 2arctg \frac{L_o + \omega \cdot t}{2} \quad (4)$$

There ω - spindle angular velocity; W - spindle movement speed.

Substituting these data into formula (3), we will determine the influence of friction coefficient and fiber moisture on the force of cotton lobes tension on the spindle. The obtained dependencies are shown in Figure 2. The figure shows that increasing the diameter has little effect on the fiber pulling force. As the fiber moisture content increases, the tension force of the cotton lob increases.

To establish the value of T, at which spindle winding with cotton fiber begins, we will use the results of field studies. Notes at the spindles are formed starting from 12% moisture content of cotton fiber. The friction coefficient in this case is $f = 0.372$ (Figure 2). Knowing these data, on the basis of Figure 2. we establish that at fiber tensile force $T = 164 \text{ g}$ and higher there are notes in all spindle designs. The fiber tension force depends on many factors, but in determining the spindle winding, we considered only the main one - the cotton moisture content. The other parameters remained unchanged. The fiber tension force was in the range of 155-177 g (Figure 2 b).

In modern vertical-spindle cotton picking machines, the cotton is removed from the spindles by self-throwing [8, 9] and with the help of pullers - by knocking down and combing out. When knocking down, the removable brushes hit the cotton and tear off some part of it and push it out along the guiding canopy. When combing, the brushes catch the fibers and drag them behind them. The brushes have sufficient speed for combing the cotton; the

circumferential speed of the points at the ends of the brushes is 9.7 m/s [10]. Scrubbing is important for removing small amounts of cotton and individual fibers lingering on the irregularities of the spindle surface. Experimental studies have established that the force of brush bar impact on a freely rotating spindle is equal to 6-12 kg [11], which is dozens of times higher than the force of flyweights in a lobe. At such force of impact of the brush bar against the cotton wound on the spindle, the cotton is knocked down, tearing into several parts or separate flying bits. When the cotton tension force $T = 164$ g and higher, the tenacity of cotton with the metal surface increases and the self-draining of cotton begins to decrease, and the pullers during combing, instead of removing individual fibers remaining after combing, begin to press them with greater force to the spindles, depending on their moisture and tenacity. In this case, the fibers remain on the surface of the spindles, forming windings.

4 Conclusion

As the moisture content of the fiber increases the force of its tension increases (see Fig. 2), which leads to an increase in the number and volume of the formed locks.

In this case, increasing the speed and force of the puller impact on the spindle does not give a positive result. Thus, winding spindles with cotton fiber are formed at humidity of raw cotton more than 12%, and tension force of cotton fiber wound on the spindle at its corresponding humidity is equal to 12% and higher. On the basis of the carried out theoretical-experimental researches it has been established that the boundary of appearance of winding of vertical spindles with cotton fiber is the value of force of tension of cotton lobe $T = 164$ g and higher depending on humidity of cotton fiber. Below this value the cotton fiber spindle windings are not formed.

On the basis of the spent researches influence of process of wrapping of spindles with cotton fibre really influences productivity of the cotton-harvesting machine is defined. Influence of winding on activity and cotton-gripping ability and their graphic dependence are established.

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