PAPER • **OPEN ACCESS**

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To cite this article: Sh Yusupov *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **614** 012143

IOP Conf. Series: Earth and Environmental Science **614** (2020) 012143 doi:10.1088/1755-1315/614/1/012143

Quality of friction drive moving spindels of cotton picking machine with vertical spindel

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Abstract. The article provides some information on the quality of cleaning the external friction (V-belt) drive, which drives the spindles of the vertical spindle of cotton picking machine, produced in the Tashkent Agricultural Tractor Plant.
It is known that the main indicator for assessing the technological process of the cotton picking machine is the level of harvesting of ripe cotton. The degree of picking depends on many factors, the most important of which is that the amount of rotation velocity of the spindle around its axis, which meets the cotton ball, does not change. Factually, the degree of picking depends on the amount of absolute velocity of the spindle tooth, which acts like a double-sided blade, especially on its direction, as determined by previous fundamental research [1-4].
The absolute velocity of the tooth is the geometric sum of the working velocity of the machine in the field V_m, the rotational velocity of the spindle drum V_b and the rotational velocity V_{sh} given by the rotation of the spindle around its axis. It is explained that since the motor of a machine used in the field is always running at rated velocity, the values of V_m and V_b remain constant, but for various reasons, the angular velocity of the spindle, i.e. the rotational velocity of the tooth, remains the same as the constructor fixed. If the velocity of a single V_{sh} changes, the absolute velocity of the tooth will change, and in some cases it will not be possible that the tooth cannot grind cotton. In a horizontal-spindle cotton picking machine, the "rigid" drive, which transmits motion to the spindles, ensures that the angular velocity of the spindle in the spinning zone is always within the limits set by the constructer. Therefore, its picking rate does not change. The disadvantages of the vertical spindle device are that the Tashkent Agricultural Tractor Plant does not pay attention to the fact that its parameters do not meet the technical requirements in the production of the above-mentioned friction drive for the spindle. For example, the tension of the three piston belts in a friction drive is not controlled in the assembly shop. Due to the fact that the tension of the belts is not the same, the pressure exerted by the belts on the spindle roller, and therefore the frictional forces that rotate the spindle, will be different. When the spindle tooth is stuck to the cotton ball and the resistance to rotation is increased, the angular velocity of the spindle decreases and the direction of the absolute velocity of the tooth becomes uncomfortable.
The article examines the tension of the outer straps of the friction drive in 28 new devices assembled at the plant and presents the results of the analysis.

1. Introduction

The government of the country pays great attention to fully harvesting cotton with the help of full machines. From 2020 on, a special resolution of the Cabinet of Ministers of the Republic of

IOP Conf. Series: Earth and Environmental Science **614** (2020) 012143 doi:10.1088/1755-1315/614/1/012143

Uzbekistan stipulates to harvest cotton without manual labor, it is necessary to produce a large number of high-quality vertical spindle picking machines at the Tashkent plant of agricultural tractor [5], [6].
Therefore, the vertical spindle cotton picking machine can be considered as an urgent problem[7][8], [9]. First of all, it is useful to mention the technical factors that affect the picking rate of a vertical spindle cotton picking machine. A spindle rolling along a cotton ball that is squeezed in a working hole between the adjacent drums of the picking machine completely pulls the cotton from the bowl, wraps it around itself, and then removes it from there[10]. In order for the spindle to wrap itself around the cotton, the teeth on the outside of the spindle must be attached to the fibers. It is known that a spindle tooth has to hang a certain amount of fiber by sinking it between several fibers, such as a double-sided blade. As the spindle rotates around its axis, it pulls the suspended fibers out of the bowl and wraps them around itself. In order for a two-sided pole to sink into an object, it is necessary to move it in a certain direction relative to the object (Figure 1).

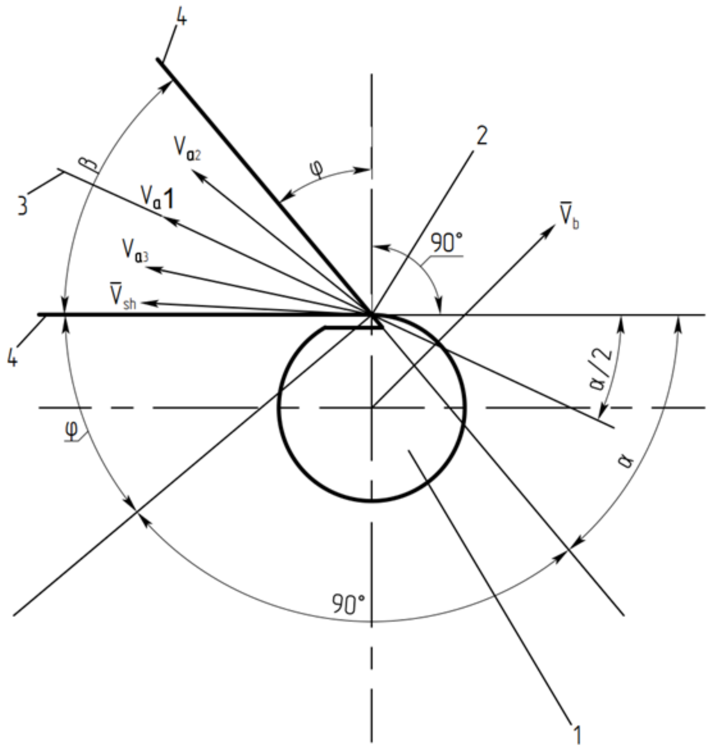

Figure 1. Description scheme of the limits of the velocity directions given to a spindle by a two-sided wedge tooth sinking into an object: 1-spindle; 2-spindle teeth; 3 - the bisector of the acute angle α of the tooth, i.e. the optimal direction of the absolute velocity of the tooth; 4 - the limits of the optimal directions of the absolute velocity of the 4th tooth.

When the direction $\bar{V}_a$ of the absolute velocity of the spindle tooth is at a bound of the angle β, the tooth penetrates between the fibers and forms a basis for hooking them. However, in order to completely pull out the wick in the boll of cotton, it is necessary to sink deeper into the tooth fibers in a very short time and hang more fibers. It is better to have a higher absolute velocity of the tooth.
Using the diagram in Figure 1, we recall that the actual absolute velocity of the spindle tooth and the spindle tooth in a running machine perform a complex motion: the working velocity of the gear machine $\bar{V}_m$ in a portable motion along with the drum rotation velocity $\bar{V}_b$ rotates around the center of the drum and $\bar{V}_{sh}$ participates in a rotational motion around the center of the spindle with a rotational velocity.

The direction and quantity of the velocity $\bar{V}_m$ are constant. The direction of $\bar{V}_b$ is constantly changing depending on the position of the spindle around the axis of the drum. Due to the fact that the tooth changes its position on the surface of the spindle rotating about its axis, the direction and the amount of $\bar{V}_{sh}$ is also constantly changing. In this case, since the absolute velocity of the tooth is a geometric sum of $\bar{V}_m$, $\bar{V}_b$, and $\bar{V}_{sh}$, it always changes its direction and quantity depending on the location of the teeth.

The constructor selectively determines the amount of $\bar{V}_m$, $\bar{V}_b$, and $\bar{V}_{sh}$ so that the limit of the optimal direction of the absolute velocity of the spindle tooth, i.e. the angle β in Figure 1, is as close as possible to the point where the tooth can meet the cotton. In the machine above, $\bar{V}_m$, and $\bar{V}_b$, were mentioned to be constant. Hence, to ensure that the velocity $\bar{V}_a$ is always within the limits of a certain angle β, the spindle must be rotated around its axis by a certain angular velocity ω_s intended by the constructor.

Therefore, it is necessary to determine on what factors the angular velocity of the spindle ω_s depend. Figure 2 shows some simplified schematics to explain this process.

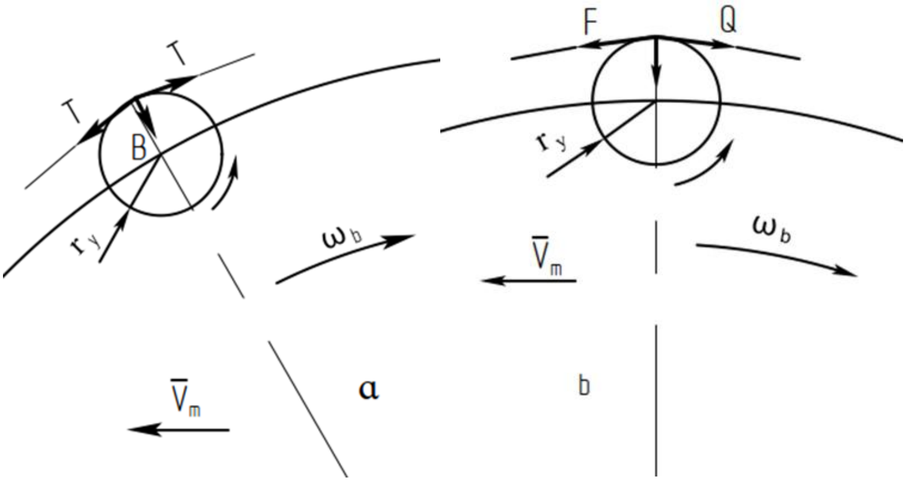

Figure 2. the scheme for the forces affecting on spindle spool: a – scheme for the pressure B exerted to the spool of the tightened belts with the force T in the static state; b – scheme for the resistance force Q of the cotton ball with the tensile force F of the belt under the pressure force B

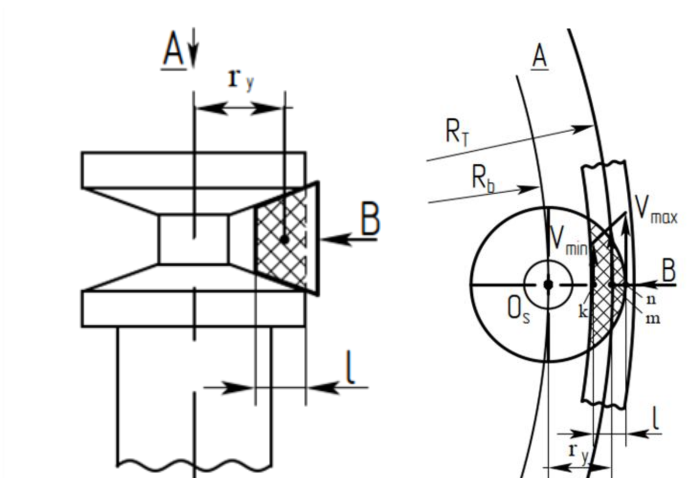

Figure 3. Description scheme for the rolling radius r_y of a spool along a wedge belt

Figure 3 illustrates the arrangement of the friction drive belt relative to the spindle pulley. Only the l length portion of the belt touches the spool. The cross section of the strip in contact with the roller represents the radius r_y of the roller rolling along the belt.
If the spool rotates at an angular velocity ω_s, the velocity in the radius O_sk, is $V_{min} = (O_s k)\omega_s$, and the velocity of the farthest point n is $V_{max} = (O_s n)\omega_s$. The mean velocity of the radius of curvature is at the point m at a distance r_y. Figures 3-a, 3-b show the rounding circle of a roller with radius R_T and r_y with point m.
If the outer band on a spindle drum in a static position is tensioned by some T force around the spool, it is necessary to find the force B applied to the axis of the spool (Figure 4).

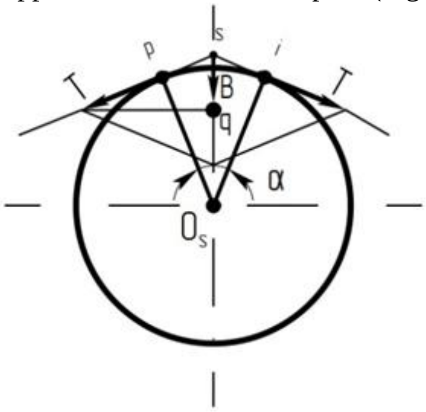

Figure 4. Scheme for determining the compression force B on the roller axis

If the number of spindles in the drum is $Z = 12$, the spool will be covered by the bands along the arc $p - i$ bounded by the angle $\alpha = \frac{2\pi}{Z} = \frac{2\pi}{12} = 30^\circ$.
From the point S where the lines of action of the forces T meet, the line of pressure B also passes. The radius $O_s p$ is perpendicular to the slope T and the angle $\angle pO_s s$ is $0{,}5\alpha$, i.e. 15°. Hence, the angle $\angle S$ from the triangle $pO_s s$ is equal to 75°. If the point q is determined perpendicular to the radial direction sO_s from the end T, then the compression force from the right angular ΔTqs $sq = sTcos75^\circ$, i.e., if the belt is tensioned by the force T,

$$B = Tcos75^\circ = 0{,}25\,T \quad (1)$$

If the coefficient of friction f between the roller and the belt is known, then the frictional force that rotates the roller in Figure 2b

$$F = Bf = Tcos75^\circ f = 0.25\,Tf \quad (2)$$

In Figure 2b, the radius of the spindle is much smaller than the radius of curvature of the spool $\sim(6-7)^\circ/$. Due to the difference, the surface of the spindle and the rounding circle of the spool are indicated by a single circle. When the rotation circle is subjected to a force F, it is shown to have a resistance force Q.
If $F > Q$, the spindle rotates at the nominal angular velocity, the picking rate is not reduced. If, for some reason, the belt tension decreases, the force F forced to rotate the spindle decreases, the spindle angular velocity decreases, and the absolute velocity of the tooth approaches the bounds of angle β in Fig. 1, or even extends beyond the boundary that results in hooking process's failure. Therefore, we found it necessary to study the quality of assembly of the friction drive that transmits motion to the vertical spindle at the Tashkent plant of agricultural machinery.

2. Literature Review

This article analyzes the reasons behind such situations. Therefore, the article begins with an explanation of the structure of the cotton picking machine, the work process.

It is well known that the degree of complete harvesting of the opened cotton crop, which is one of the most important agro-technical indicators of a cotton picking machine, depends on the velocity of rotation of the spindles around its axis. The scheme of rotation of the vertical spindle around its axis is shown in Figure 5 [11].
The drums are rotated in opposite directions to forcibly insert a wide cotton ball into a very narrow (28–36 mm) working hole between adjacent drums in a row. Fixed belts 12 and 13, which cover the outside and inside of the spools, are used to transmit the rotational motion of the drum to the spindle. As the center of the spool moves forward due to the rotation of the drum, the spool rotates along the belt due to the frictional force generated between the surface of the spool and the stationary belt, rotating the spindle around its own axis [12].
As a result, the worker hangs the cotton wool, which is pressed against the branches of the cotton stalk, which is squeezed in the hole, and pulls it out of the bowl in the form of a long stalk. The cotton wool is wrapped around the surface of the spindle. The spindle, which is wrapped around the cotton, continues to move with the drum, falling off the outer straps, and continues to rotate with inertia. The roller then climbs onto the inner belt and brakes under the action of friction with it - it stops for a very short time and changes the direction of rotation.
During braking, the cotton wool wrapped around the spindle is removed from the tooth by the force of inertia. This means that about 80% of the cotton in the spindle that has not yet reached the separator brushes is separated from the spindle by reverse rotation [2]. The spindle, which rotates in the opposite direction, passes behind the tooth towards its tip, and the separating brush removes the juicy dirt that sticks to the tooth with the remaining cotton [1].

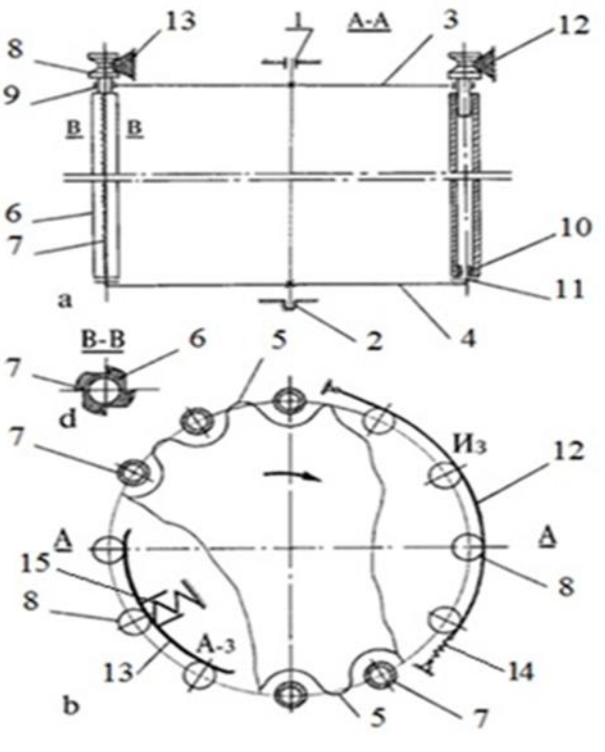

Figure 5. Spindle drum scheme: a is side view; b is appearance; d is cross-section of spindle; 1 is superficial disk; 2 is sub disk; 3 is upper disk drive; 4 is sub disk drive; 5 is clamping cylinder; 6 is spindle cross-section; 7 is spindle tooth; 8 is spindle coil; 9 is upper spindle bearing; 10 is lower spindle bearing; 11 is spindle-mounted finger; 12 is outer ribbon; 13 is strap; 14 is spring-tightening spring; 15 is spring-clamping spring.

3. Research Methodology

Our article is to study how to control the parameters of a friction drive that transmits rotational motion to the spindles during the production of a vertical spindle cotton picking machine at the Tashkent Agricultural Tractor Plant. A set of frictional drive belts (Figure 6) is delivered to the assembly shop ready. However, it is not checked with special equipment before mounting it on the hardware. It is also not checked that the tension of the three straps is the same after installation on the device. But we are allowed to control the sets of straps that are installed on the device, so we are very grateful.

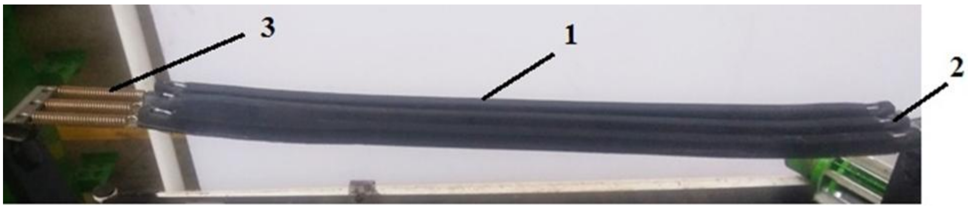

Figure 6. Set of ready straps: 1- simply wedge straps; 2- single hooks connected by straps; 3 - springs tightening the belts separately.

We developed a very simple device to study how much the tension of the straps mounted on the device is the same (Figure 7). The column 2, which is mounted on the base of the equipment, is connected to the hinge relative to the base 3, which is the second column. The tops of the poles are hooked to hang a set of straps. The hanging straps are tightened using a special screw. With the screw, the rotating column is moved away from the tension and the set of straps is tightened. Initially, the tension lengths of the 168 springs in the middle of 56 tightened sets, mounted on the front drums of 28 apparatus (using a caliper with an accuracy of 0.1 mm) were measured and their arithmetic mean $\bar{l}_p$ was determined. Screw 5 is used until the length of the middle ring of the set of straps mounted on the device (Figure 7) is equal to $\bar{l}_p$.

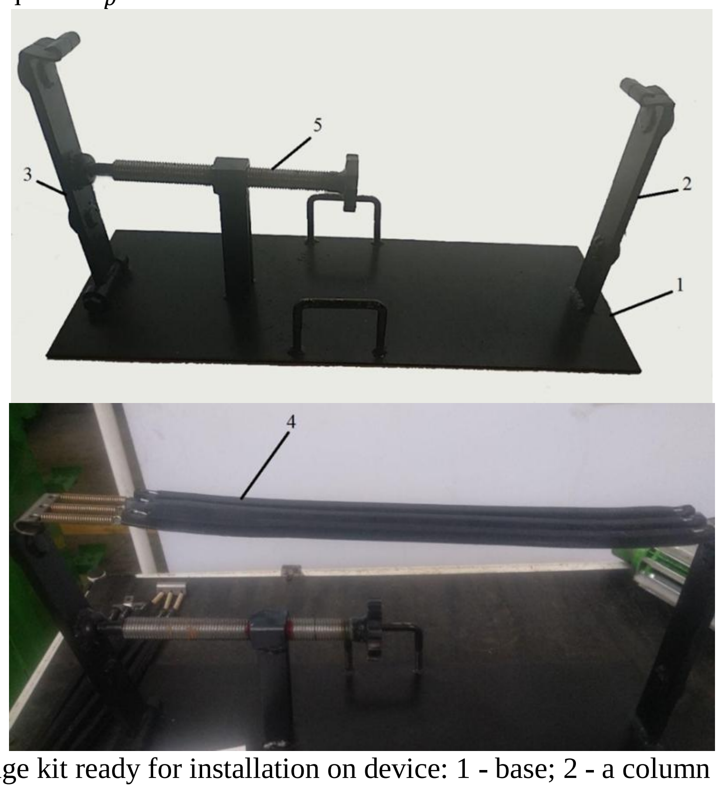

Figure 7. Strain gauge kit ready for installation on device: 1 - base; 2 - a column of strain mounted on a base; 3 - hinged column on base; 4 - a set of straps mounted on the hooks of the column; 5 - screw tightening the set of 5 straps.

As a result, it can be assumed that the set of straps under study is strained to the extent that it is set up on the device. Our goal was not to directly measure the tension of each strip, but to estimate that the strains would be the same. Because we have simplified the work a bit, considering that the workload is very large. To indirectly estimate the tension of the belt, we placed a load of a certain weight in the middle of the tensioned strap, measured the amount of bending Δh from its initial tension, and selected the method of analysis required. As a result, without complex instruments, it was possible to complete the measurements in a short time and estimate the generalized parameters of the belt tension with indirect indicators.

The bending of the tensioned belt under the influence of the suspended load is measured as follows (Fig. 8b): the spring in the middle belt of the set of straps attached to the equipment is tightened as stretched as to a predetermined length $\bar{l}_p$.

Beforehand all the strap was marked with paint at a certain distance in the spring. The initial height h_∂ of this mark on each tensioned strip relative to the base of the equipment is measured three times, and the recorded average value is copied down in a notebook (Figure 8a). A load of weight $G = 15\ N$ is fastened to the stretched strip marked with paint, and the next height h_k to the base is measured again. $\Delta h = h_\partial - h_k$ is taken as an indicator of the curvature of the strap.

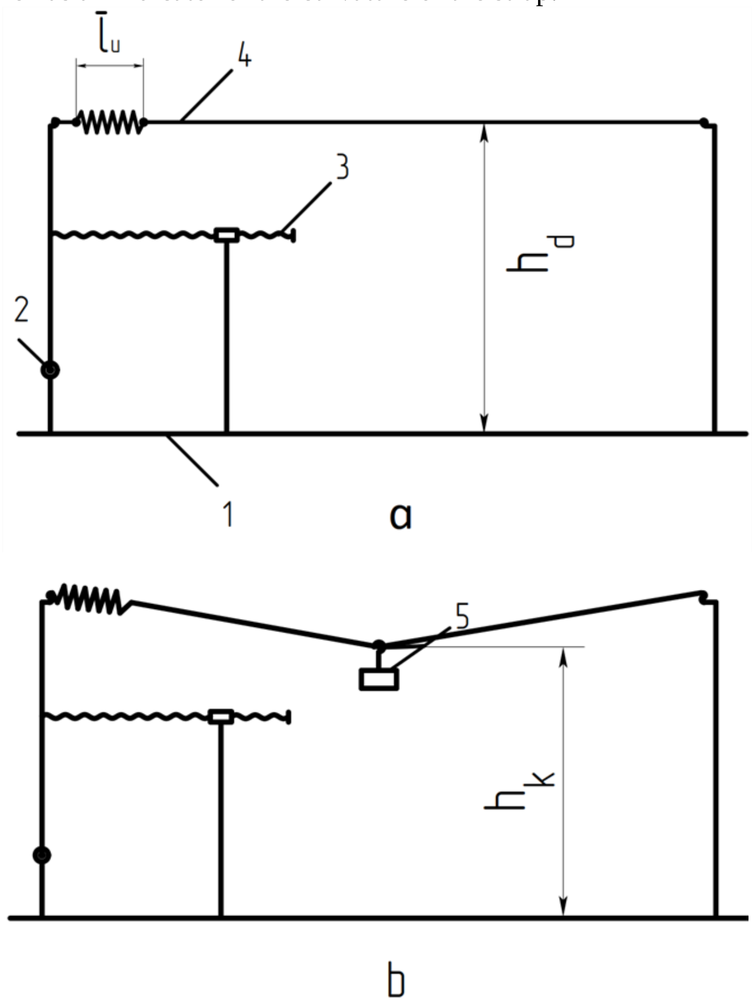

Figure 8. Scheme for finding the amount of belt bending Δh: 1 basis; 2 hinges; 3 belt tensioning screw; 4 the initial position of the strap; 5 load.

4. Analysis and Results

Given that the tension of the straps in the assembled strap sets depends not only on the position of the spring, but also on the quality of the straps sewn to the hooks, special equipment described above is used to analyze the case of the strap sets prepared for mounting on the dials.

The set of straps set up on the device is tightened by means of an adjusting screw until the length of the middle spring of the belt in the elongated position of the springs of the kit mounted directly on the apparatus was equal to $\bar{l}_u = 66.4$ mm. Then, the height h_∂ of the inner surface of each strip relative to the base of the equipment is measured (to the nearest 1.0 mm). A hook load (scales) was then placed in the middle of each strip at a pre-determined location, and the height h_k of the inner surface of the belt relative to the base was measured.

The difference in heights Δh is taken as the amount of bending of the belt. It is found that the arithmetic mean of the bending of 168 tensioned bands under 56 sets under the load weight is $\Delta h_u = 28$ mm, and the mean square deviation is s = 1.6 mm.

Of course, it would be possible to determine the elongation of the springs by the amount of Δh and the tensile force by the elongation. However, taking into account that the amount of Δh also depends on the quality of sewing the strap on the hooks, we consider it permissible to indirectly assess the quality of assembly of kits with the value of Δh. Studies have shown that Δh is not the same, and that the mean squared deviation σ, which represents the variability of the measurements, is large. This means that the tension of the belts in the kits, that is, the non-uniform frictional forces (gravitational forces) generated by the belts on the spindle pulley, is a shortcoming of factory-made devices. The larger σ, the lower the quality of the friction drive. So, first of all, the straps in one set must be equipped with springs of the same size. In addition, we believe that it would be useful to install a device that adjusts the force of each spring in the set of belts mounted on the apparatus in the same way.

5. Conclusions

1. For any spindle in order to pull the cotton out of the cotton ball, its teeth must penetrate the cotton fibers, sink, and hook. To do this, it needs to make sure that the absolute velocity of the tooth, which works like a double-sided wedge, first of all, the direction, and secondly the amount, meet certain requirements. The absolute velocity of the tooth is the geometric sum of the working velocity of the machine in the field $\bar{V}_m$, the rotational velocity of the spindle drum $\bar{V}_b$ and the rotational velocity of the spindle surface rotating around its axis $\bar{V}_{sh}$. $\bar{V}_m$ and $\bar{V}_b$ of the machines working in a field machine are not changed. For a variety of reasons, there is a high probability that the angular velocity of the spindle rotating around its own axis will decrease, which can drastically reduce its ability to spin the cotton due to changing the optimal direction of the absolute velocity of the spindle tooth.

2. Due to the fact that the amount of compressive force applied to the spindle spool by the friction drive belts that rotate the vertical spindle is not always the same, the frictional force between the belt and spool sometimes gets reduced, the variable resistance of the cotton bush will always not exceed the guaranteed level, the spindle angular velocity decreases, and the picking rate will decrease. Hence, it is necessary to increase the traction capacity of the vertical spindle friction drive. Then the angular velocity of the vertical spindle in the dialing chamber is stable, as in the horizontal spindle machine, and the picking rate does not change.

3. We have observed that the Tashkent plant of agricultural machinery plant does not control the tension of friction drive belts, which has to comply with regulatory documents, installed on devices that have not yet been delivered to consumers. to ensure compliance with regulatory documents. We believe that the improvement of control operations in the technology of spindle friction drive assembly to significantly improve the quality of machine operation will have a significant effect.

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