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Possibility of replacing the V-belts of the friction drive of vertical spindles with poly V-belts

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Possibility of replacing the V-belts of the friction drive of vertical spindles with poly V-belts

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Abstract. The main indicator of the work of a cotton picker is its completeness of harvesting in one pass. For a vertical spindle machine, this indicator is relatively low and not stable. The main factor giving rise to these shortcomings is the quality of functioning of the friction drive of the spindles. In the existing version of the friction drive, the tension of the V-belts turns out to be not the same and uncontrollable, which is why the traction capacity of the drive does not ensure the stability of the assigned angular speed of the spindle, which violates the conditions for gripping the cotton by the spindle tooth. Previously, the authors published studies of a serial drive that revealed some shortcomings in their manufacture and operation. The article describes the essence of improving the operation of the spindle friction drive: the authors show that if poly-V belts are installed instead of conventional V-belts: the geometric sliding of the spindle roller will decrease, which will improve the energy consumption of the drive; the girth of the roller with the belt will improve, because V-ribbed belts are more elastic than single V-belts; the degree of compression of all the belt wedges, planted on a common power belt to the roller, will be more the same than individual V-belts. These indicators, according to the authors, will improve the stability of the technological process of capturing cotton by the spindle tooth, which will increase the completeness of the harvest of the entire machine.

1. Introduction

The vertical-spindle cotton pickers, which are proudly technical in Uzbekistan, are simple in design and require low operating costs. Therefore, they are more demanded by farmers. However, these machines are somewhat inferior to horizontal spindle machines in terms of completeness of collection. There are many reasons for the lower completeness of the collection of vertical-spindle devices. However, in our opinion, the main reason is the instability of the spindle speed during assembly. The instability of the high-speed mode is predetermined by the unstable functioning of the friction drive of the spindles, which consists of three V-belts. The drive of the horizontal spindle is "rigid", which in the collecting chamber always provides the specified angular speed of the spindle, which makes its collection completeness stably high.

2. Materials and methods

In order for the reader to easily understand the essence of the issue under study, we will make a short excursion into the 1950s, when Acad. M.V. Sablikov created the theoretical foundations of vertical-spindle devices. His work on kinematic studies of the friction drive will be continued by V.I. Lazunov, U.X. Mansurov, I.X. Mints, V.M. Shexovtsev and others [3, 4, 5, 6, 7, 8, 9].

In Figure 1 we give a diagram of the spindle drive mechanism from the book by M.V. Sablikov [3]. With its help, we will try to explain the effect of friction.

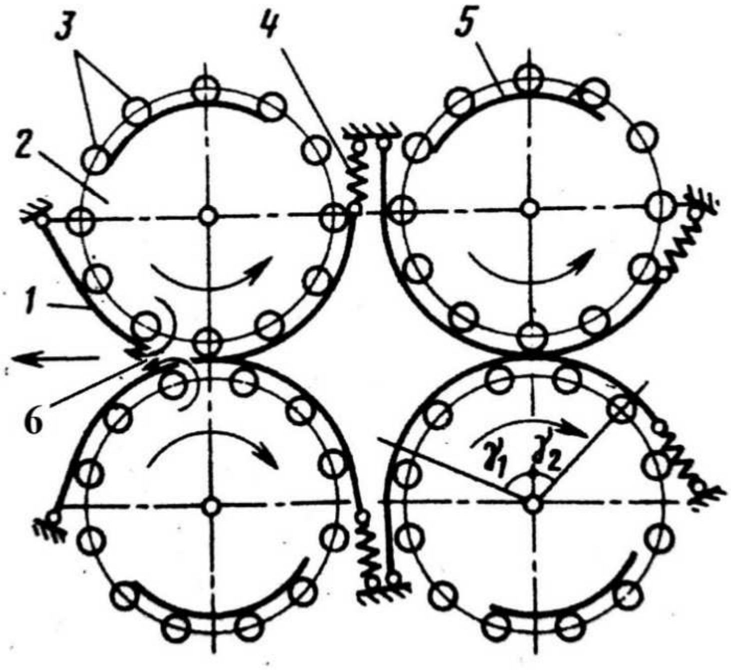


Figure 1. Spindle drive mechanism diagram: 1-V-belts; 2- spindle drum; 3-spindles; 4- tension springs; 5- belt for reverse rotation of the spindles; 6- working slit.

The drive on the technological process of collection. As the unit moves in the $\overline{V}_M$ direction, the spindle drums of one pair rotate towards each other tighten the cotton bush into the working slit 6, where contact of the spindle with the cotton in the bolls sash occurs. The spindle rollers, when moving together with the drum 2, roll over the outer belts 1 and rotate the spindle in the direction of its teeth. The teeth capture a slice of cotton. The rotating spindle winds it on itself and retrieves it from the sash. The process of passing the bush through the working slit lasts no more than 0.1 seconds. For such a very limited time, the spindle must have time to wholly extract the cotton slice from the sash and reel on itself. Further, the spindle with the wound cotton falls into take-off area, where, to facilitate the unwinding of the wound lobule, the spindle rotates in the reverse side, i.e. back of the tooth forward.

The spindle tooth is similar to a dihedral wedge, so it can penetrate into cotton only if the direction of its absolute speed is within a small angle β Figure 2, b this is explained in [2]. In the process of moving the spindle by the drum at the entrance to the working slot, the direction and magnitude of the absolute speed $\overline{V}_b$ of the drum changes along the centers of the spindles. In addition, because the spindle is not rigidly connected to the drive belt, its tooth can be anywhere along the circumference of the spindle, i.e. the spindle speed $\overline{V}_S$ changes its direction. The absolute speed of the tooth is the geometric sum of the constant working speed of the machine $\overline{V}_M$, the peripheral speed of the drum along the centers of the spindles $\overline{V}_b$, the direction of which changes as it moves along with the drum, as well as the peripheral speed of the tooth $\overline{V}_3$, of the spindle, which also changes as the location of the tooth changes a spindle rotating around its axis (Figure 2, a). Thus, when adding the peripheral speed of the tooth $\overline{V}_3$, with $\overline{V}_M$ and $\overline{V}_b$, we obtain the absolute speed $\overline{V}_a$ of the tooth, which is variable both in magnitude and direction. Therefore, its direction does not always turn out to be within the angle β, where the tooth is considered active. Summarizing the definition of the absolute speed of the tooth $\overline{V}_a$, we note that its direction and magnitude depend on the values of the speeds $\overline{V}_M$, $\overline{V}_b$ and $\overline{V}_3$. On the field at the machine $\overline{V}_M$ and $\overline{V}_b$ are constant in magnitude, and $\overline{V}_3$ can change, because the contact mode of the spindle roller with the friction belt is not maintained unchanged. Consequently, ensuring the calculated angular speed of the spindle under the resistance of the bushes is an urgent task [10, 11, 12, 13].

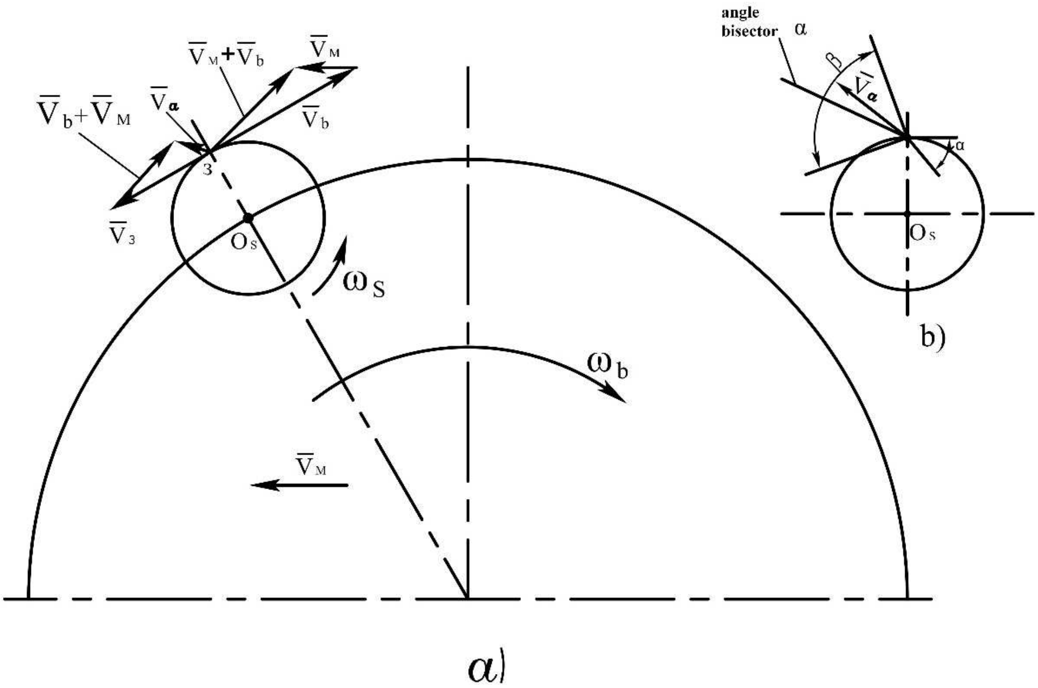


Figure 2. Example of determining the absolute velocity $\overline{V}_3$of a tooth (a) and a schema explaining the effect of the direction $\overline{V}_a$ on its trapping ability (b)

The reason for the inconstancy of the contact mode of the roller with the belts is the lack of control over the quality of the assembly of the friction drive at the factory and in the farms where these machines are operated. Investigating the condition of the friction drive, we found that when assembling the drive, there is no instrumental control, for example, the tension force of the belts. In [2, 3, 4] we gave the results of the corresponding measurements: almost 50% of the devices do not have the same belt tension in one set of the drive, and 60% of the devices have a much lower drive traction capacity. Thus, unfortunately the serial friction drive of many machines does not provide the assigned angular speed of the spindle, which dramatically worsens the completeness of the cotton harvest. The authors in [2] proposed to supply the harvesting machine with a simple screw device that allows adjusting the tension of individual belts. However, this will not solve the problem, so the authors believe that the friction drive of the vertical spindles should be retained, but it should be improved by installing V-belts instead of the usual V-belts, with minor changes in the design of the spindle rollers, as well as the initial part of the belts[14, 15, 16, 17, 18].

The wedges of the poly V-belt are “planted” on one power (traction) base in the form of a flat and elastic tape. When installing such belts on a friction drive, the tension of all wedges, therefore, their pressure on the roller, the friction forces created by them will be the same[19].

If on a serial drive, in which the tension of the belts is not controlled, the tensions of the individual belts are not the same, they create different magnitudes of friction force, which equalize lead to energy losses.

Thus, the installation of one V-belt instead of three V-belts will ensure the same pressure of all the wedges on the roller, which will dramatically reduce the geometric slip on adjacent wedges, and reduce energy losses. If we consider that the rolling radius of the spindle roller on the belts ($r_к \approx 12$ мм,) is very small, and conventional v-belts are recommended for use on pulleys with a radius of $r_к > 31$ мм, it becomes clear that the best adaptation to the conditions of the spindle drive of V-belts, since they are recommended for $r_к \approx 20$ мм. The presence of a stabilizer in the initial part of the belts will allow selecting the desired braking mode when reversing, so that at the beginning of the collision of the roller on the V-shaped wedges, their meeting occurs at a low, even at zero angular speed of the spindle, which will increase the service life of the belts (Figure 3). The possibility of installing the initial part of the belt in a vertical plane due to the oriented installation of the hinge of the wide base of the belt to the frame of the device will prevent its fluctuations, which will improve the braking of the roller on the stabilizer.

In the area of cotton removal from the spindles, the stabilizer braking mode should provide an optimal mode of self-discharge of cotton from the spindles when it is reversed.

3. Research methodology

The disadvantages of the used drive are, firstly, the central angle β of the roller wrap around the belt is very small, no more than 30 ° with the number of spindles z = 12 pcs. (Figure 4). Secondly, the impossibility of providing the same tension for all belts, they are pressed against the roller grooves in different ways and create friction forces of different magnitudes, which is why a belt with a minimum friction force somewhat slows down the maximum friction force of another belt. This leads to a loss of energy.

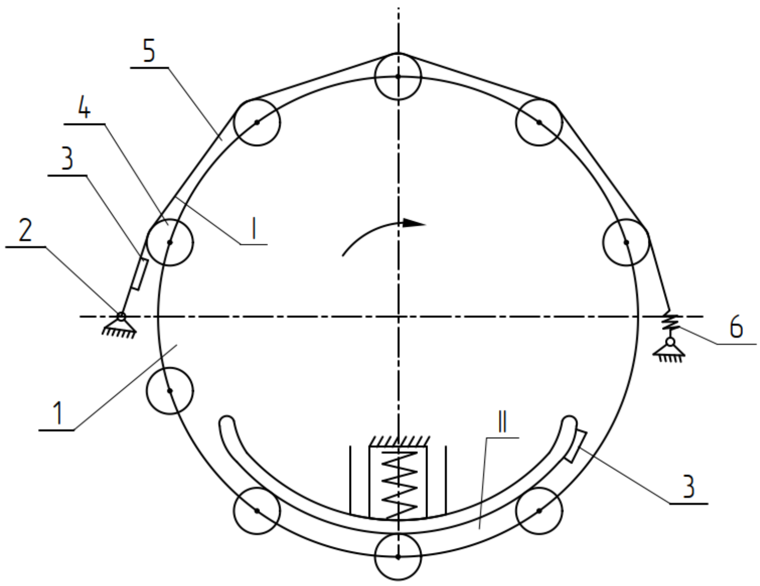


Figure 3. Diagram of the installation of a poly V-belt belt with a wedge-shaped stabilizer on the drum: 1-the spindle drum; 2-the hinge of the belt attachment to the frame; 3-the stabilizer; 4 - roller the spindle ; 5-the flexible belt; 6-the belt tension springs; β-the angle of the belt girth of the roller.

Therefore, the spindle roller drive operates in excellent mode than conventional V-belt drives. B-Third, the belt is wedged into the groove of the roller with a sufficiently long contact spot (Figure 4). The rolling radius of the roller in the outer H and the inner one B the boundaries of this spot turns out to be of different magnitudes, why is the circumferential velocity of the outer point H of the spot much greater than the velocity of the inner point B, i. e. $V_H > V_B$. Due to the difference V_H and V_B the roller 1 rolls along the belt 2 with a large geometric slip, reducing the efficiency of the drive.

4. Analysis and results

These disadvantages together dramatically reduce the traction capacity of the serial drive, which is why at the moments of maximum resistance when the teeth of the spindle meet with a strongly compressed bush, the angular speed of the spindle can significantly decrease. The completeness of the cotton harvest is reduced.

The ribs of the V-belt are wedged into the grooves of the roller to a smaller depth, so the geometric slip will be reduced, and therefore the traction capacity of the drive and its efficiency will increase.

The ribs of the V-ribbed belt have a 4 times smaller cross-sectional area compared to the serial V-belt. They have less bending stiffness, more flexibility. Therefore, with the number of spindles on the drum in 12 pieces, these flexible belts will provide the angle of the spindle roller wrap almost up to $\alpha = 30^{\circ}$, while the more rigid serial belt is installed almost tangentially, provides a much smaller contact angle (Figure 3 and 4).

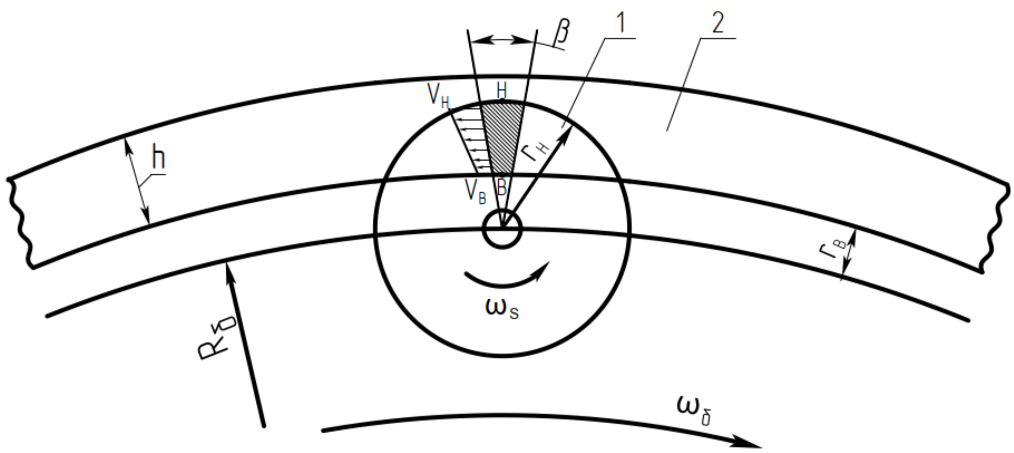


Figure 4. Diagram of the contact spot of the spindle roller with the V-belt: 1-roller the spindle; 2-the belt.

According to M. V. Sablikov, the value of the angle of girth α by the belt of the roller strongly affects the value of the circumferential efforts K that rotates the spindle roller [5]:

$$K = P_1(\mathrm{e}^{f\beta} - 1)/\mathrm{e}^{f\beta}, \quad (1)$$

where P_1 is the tension of the V-belt branch running off the roller;

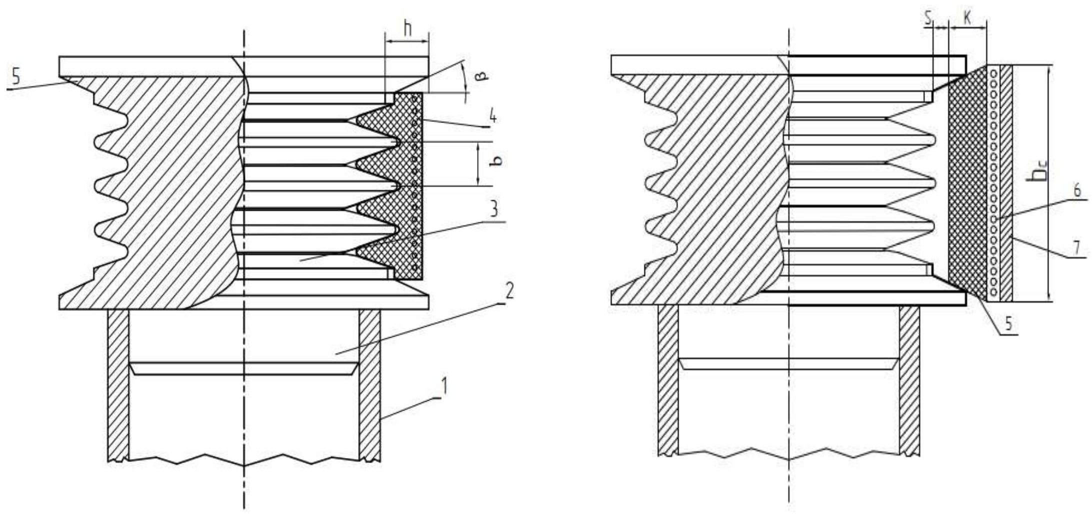
f - coefficient of friction belt - roller.

The dependence (1) can be applied without large mistakes for the poly -V-belt as well. When equal P_1 and f, a larger angle β of the girth will provide for (1) a larger K of the v-belt, t. to. β is in the power e (Figure 4).

Consequently, the possibility of the increase in the angle of the roller wrapping by the belt will also increase the traction capacity of the recommended drive and its efficiency.

Due to their small size, the edges of the poly V-belt come into contact with the grooves of the roller in the form of a spot of shorter length, which makes the speed difference $V_{\mathrm{B}}$and V_{H} small, reducing the geometric slip compared to a conventional V-belt (Figure 4).

As it is known, spindles with rollers are installed on the periphery of a drum with a diameter of 292 mm. When the drum rotates, the rollers are carried over the zones of the apparatus. In the proposed drive, when the spindle enters the working area of the device (Figure 5), the spindle roller runs over the beginning of the stationary belt. In order to orient the collision of the grooves of the roller 3 on the fixed longitudinal working ribs of the belt 4, the spindle roller 1 is equipped with an oblique flange 5 (Figure 5a). The groove formed by these flanges will include the stabilizer 4 (Figure 5b) installed on the base of the poly V-belt in front of the wedges. The stabilizer is a piece of a V-belt with a width b_c, and the height h of the flange 5 is greater than the height of the base of the rib of the stabilizer belt, and the angle of inclination of the flange to the base α is less than the friction angle. The beginning of the working section of the outer and inner belts, where the roller runs, are equipped with a wedge-shaped stabilizer 4 (Figure 3 and 5). When the roller hits the stabilizer, its oblique flanges abut against the edges of the stabilizer, which is why the spindle is rapidly decelerated to a stop. This orientates the working wedges of the belt into the grooves of the roller, which will reduce the wear of the longitudinal ribs 2 of the drive belt in the initial section (Figure 5.b)



a) b)

Figure 5. Friction drive of vertical spindle made of poly -V-belt: a-installation of the poly V-belt 4 relative to the grooves 3 of the roller 2 of the spindle 1; b- installation of the stabilizer relative to the flange 5 and grooves 3 of the spindle roller.

Stabilizer 4 is installed on a single base 1 with a poly V-belt 2 (Figure 6). The width of the stabilizer b_c is sufficient to ensure the contact of its ribs with the flanges 5 of the roller (Figure 5, b). The height of the stabilizer K provides a gap S between the ribs of the roller and the base of the stabilizer (Figure 5, b).

A metal plate 3 is also attached to the base of the belt, ending with a hook for installation on the drum frame.

The rolling radius of the roller flange on the stabilizer is much greater than the rolling radius of the spindle roller on the drive belt. Therefore, by selecting the regularity of the change in the pressure of the stabilizer on the flange, the optimal mode of braking and acceleration of the spindle at the initial section of the internal and external belts during its reversal is easily ensured. This will allow the roller to run over the wedges of the poly V-belt almost in a stopped state, which is why the value of the adopted angular accelerations is preserved, which allows maintaining the adopted mode of braking and acceleration of the spindles.

As a result, the height of the spindle roller will decrease by almost 2 times, the metal and energy consumption of the drive will decrease, the moment of inertia of the entire spindle will decrease, which will facilitate the operation of the drive.

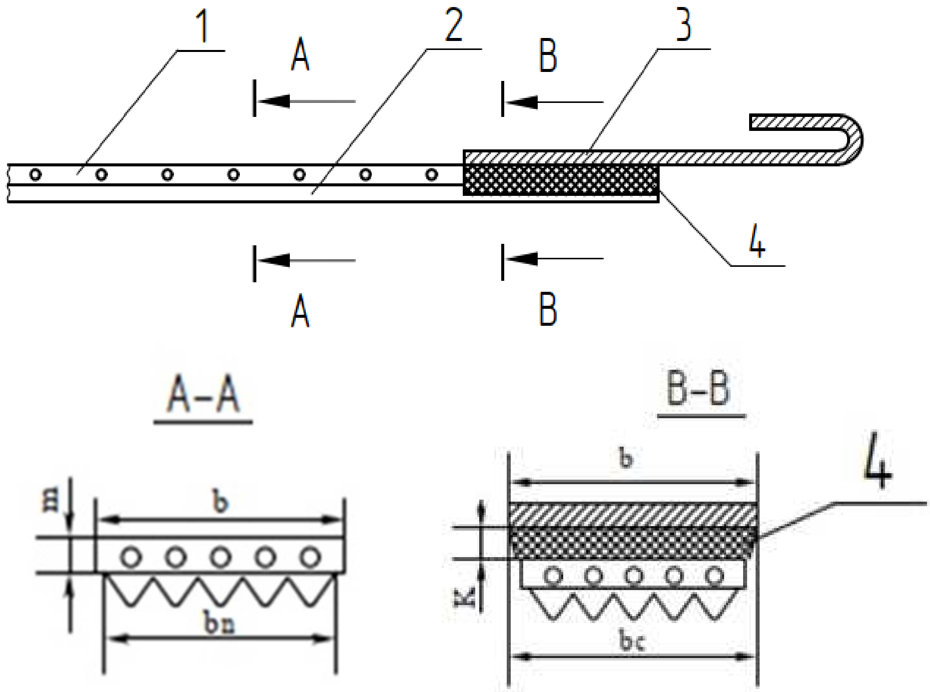


Figure 6. Wedge-shaped stabilizer: 1-the base of the poly-V-belt; 2-the belt wedges; 3-the mounting hook; 4-the stabilizer

For a preliminary comparison of the traction capacity of the V-belt, an experiment was conducted on the simplest device (Figure 7). A piece of belt 2 was glued to the fixed rail 1. Load G was symmetrically suspended from the roller axis.

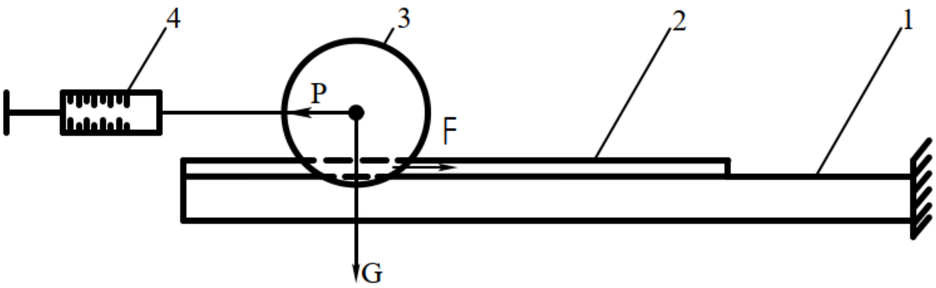


Figure 7. Scheme for determining the friction force of a non-rotating roller on a belt: 1-rail; 2 - piece of belt; 3-roller; 4-dinomameter.

The axis of the roller was rigidly sealed to its body, which is why, when a force P was applied, which tends to move the roller, it did not rotate, but slid along the belt. A weight G = 30N is suspended from the axle, which is the normal pressure of the roller on the belt. The cable tied to the roller axis was stretched strictly horizontally using a dynamometer. With a gradual increase in P, the roller moved along the belt. The dynamometer reading at the moment of the roller movement was recorded and taken as the friction force between the roller and the belt. The repetition of the experiments was 10.

In the first version, a piece of a serial set of V-belts was laid (glued) strictly horizontally on the rail, on which a serial spindle roller was installed.

In the second version, a piece of a poly V-belt was laid on the rail, on which an experimental roller was installed according to Figure 5. Load G in both variants remained the same.

As a result, it was found that the friction force of the experimental roller on the poly -V-belt was 2.5-3.0 times greater than the friction force of the serial roller on the serial belts. This result was the first tentative basis for starting research on the replacement of V-belts with poly -V-belts.

5. Conclusion

The design of the serial friction drive of the spindles of vertical-spindle cotton harvesters does not always ensure the proper speed mode of the spindles in the working area of the device, which dramatically worsens the gripping ability of the spindle tooth. This is clearly the main reason for the low completeness of the assembly of the machine, this is due to the fact that all three V-belts are mounted separately. Their tension is provided by individual tension springs. However, the springs often have different characteristics, which is why the belts are not stretched equally and to an insufficient extent. Therefore, the traction force of the drive is insufficient to provide the spindles with sufficient angular velocity when the resistance of the bush increases in the collection area, so the gripping ability of the tooth, i.e., the collection, of cotton, is sharply reduced.

Therefore, it is necessary to modernize the friction drive by replacing conventional V-belts with poly V-belts, which have a greater traction force, which is why their use in mechanical engineering, especially in small power transmissions, is expanding.

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