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Stabilizer for reversing vertical spindles in the drum removal area of cotton-picking apparatus

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Stabilizer for reversing vertical spindles in the drum removal area of cotton-picking apparatus

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Abstract. The main indicator of the quality of the cotton harvesting machine is the completeness of collecting the grown crop into the bin, which is usually 3-4% lower than the completeness of collecting spindles. This is because the remover of vertical-spindle machines does not fully remove the cotton bobbins from the spindles. Part of the cotton wound on the spindle is carried away into the working zone without being removed. This phenomenon is called "cotton carry-over". According to previous authors, "Carry-over" reaches 3-4% of the spindle collection completeness. This happens because the spindle roller, after leaving contact with the external belts, rotates by inertia and when it encounters the inner belts of the removal zone, the spindle suddenly slows down to change the direction of rotation. Here, due to the braking, the cotton bobbin falls off the spindle by "self-release". If the braking is excessive, some cotton bobbins lose their grip on the spindle and remain on it as a free ring. If the brush remover does not remove this "ring", it is "carried over" by the spindle into the working zone. This process reduces the completeness of the collection in the hopper. In order to ensure the stability of cotton collection by the spindle, it is necessary to provide an increased pulling force of the friction drive in the working zone. In our experiments, this was achieved by replacing the conventional V-belts of the drive with multi-ribbed belts. Multi-ribbed belts increase the pulling force by 1.5 times because their grip with the small radius roller is improved. In the removal zone of the drum, it is also necessary to install multi-ribbed belts, which, due to their better grip, brake the spindle more sharply and increase carry-over. To reduce this process, a stabilizer is installed on the head of the reverse rotation brake, which allows the braking process to be adjusted. This article provides materials explaining the design of this stabilizer.

1. Introduction

The technological process of the vertical-spindle cotton picking apparatus involves reversing the spindles in the working zone of the brush picker to facilitate the removal of cotton bolls from the spindles. Therefore, if the friction drive belts in the working zone of the drum wrap around the spindle rollers from the outside, then in the cotton removal zone from the inside [1,2]. If the spindles of the right drums rotate clockwise in the working zone, then in the removal zone they rotate counterclockwise (Figure 1).

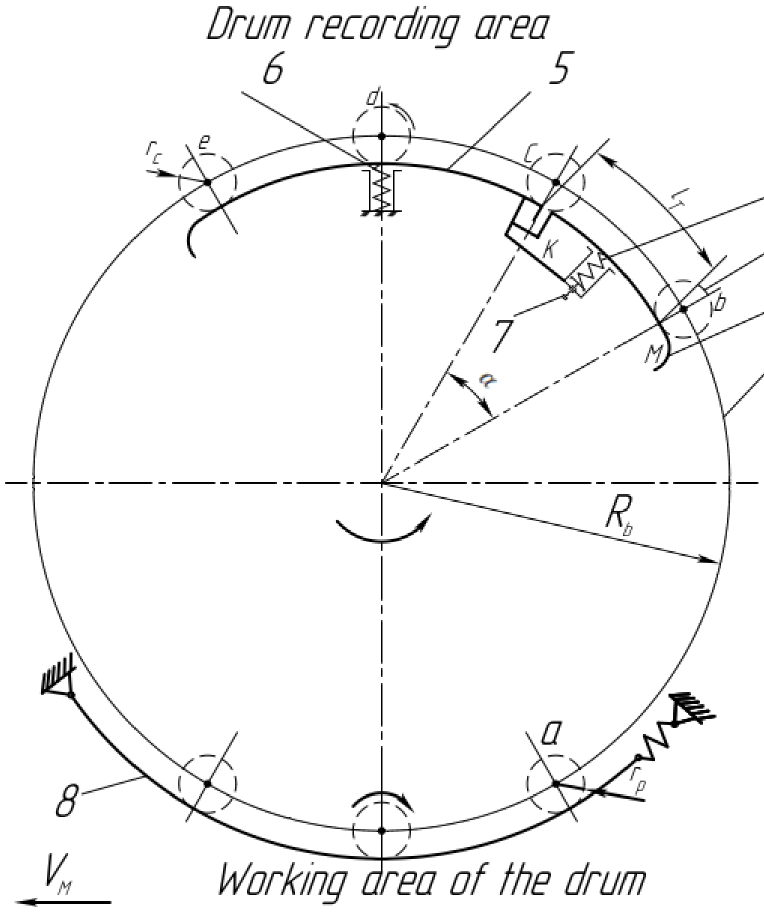

Figure 1. Stabilizer scheme for the reverse zone of spindles when entering the drum removal zone: 1 - spindle drum along the spindle axes; 2 - head part of the reverse rotation brake pad; 3 - rolling circle of the spindle roller on the inner belts; 4 - spring of the head part of the brake pad; 5 - inner belt on the reverse rotation brake pad; 6 - spring that presses the brake pad with the belt against the spindle rollers. 7 - screw; 8 - external belts; a - position of the spindle roller descending from the external belts; b - beginning of contact of the roller with the inner belt of the head part of the brake pad; C - moment of convergence of the roller with the head part of the brake pad; d - moment of the roller being opposite the spring of the brake pad; e - moment of the roller divergence from the inner belts; r_c - rolling radius of the roller on the inner belts; r_p - rolling radius of the roller on the outer belts.

After the rollers exit the contact with the external belts 8, the spindles continue to rotate clockwise due to inertia. When the rollers come into contact with the initial portion 2 of the internal reverse brake belts 5, they are slowed down on a length of belts of some distance l_T, momentarily come to a stop, and then begin to accelerate in the opposite direction, i.e. towards the back of the tooth [3], [4]. This process causes the unwinding of the cotton strip from the spindle due to the forces of inertia. Before the spindle reaches the brush stripper, the main part of the strips (up to 80%) is removed from the spindle by "self-dropping" [5]-[7]. The remaining cotton on the spindle is then removed from it by the action of the stripper brushes on the back of the tooth.

Full cotton removal by self-dropping occurs when the spindle is moderately slowed down. When the negative angular acceleration is small, only a small amount of cotton is removed by self-dropping, while at very high accelerations, the cotton package loses contact with the surface of the spindle and remains on it in the form of a free ring. This ring, in the form of a "flyer", is carried by the spindle into the working area of the drum [5], [8]. This reduces the amount of cotton directed to the machine's hopper.

Thus, the process of reversing the spindle when it enters the drum removal zone should be carried out in a limited mode compared to when it enters the drum collection zone.

In our case, such a spindle braking mode should be provided by the removal zone stabilizer. The stabilizer is actually the head part of the reverse brake with a separate piece of a modernized multi-ribbed belt.

The overall length, radius of curvature, the nature of the bending at the beginning and end of metal bracket 5, and all parameters of the spring device that presses the entire bracket 5 with a belt to the rollers 3 of the spindles, i.e. the characteristics of the cylindrical spring 6, are preserved as in the standard drive. Only the initial part 2 of bracket 5 of a certain length l_T is hinged to the main part of the bracket at point K (figure 1).

In addition, it is taken into account that the width of the poly-V belt with five ribs of South Korean manufacture is $b_{pk} = 17.8\, mm$. In the standard drive, three separate V-belts are installed [9], so the total width of this set of belts is $b_{kor} = 45\, mm$, which is much larger. The height of the metal bracket in the standard drive is adapted to b_{kor} and is equal to 45 mm. In our case, therefore, the metal bracket should have a width slightly larger than b_{pk}, i.e. about $b_{pk} + 2.5 = 20.3\, mm$, which corresponds to the dimensions of the rollers of the updated spindle design. Therefore, the new bracket will have a mass of 325.6 g, while the mass of the standard bracket was 740 grams.

2. The action of the stabilizer

The main parameter of the stabilizer is its length l_{T}. The spindle, the roller of which has come off the external belts of the working zone a of the drum rotating at an angular velocity of $\omega_b \approx 12\, rad/s$, is moved to the beginning of the b brake pad of reverse rotation after some time t_i. It is technically impossible to instrumentally determine the time t_{T} for the spindle to come to a complete stop. Therefore, we solve this problem indirectly - our observations of the operation of many spindle drums of machines participating in real crop harvesting in the fields have shown that the initial part of the serial wedge belt on a length of $l_{\text{T}}. \approx 60 - 70\, mm$ wears intensively, which can be measured visually. We consider that at $l_{\text{T}}. = 60 - 70\, mm$, satisfactory "self-discharge" and acceptable "draft" of cotton are provided on serial devices. We believe that the intensive wear of the belt occurs precisely during the deceleration of the spindle, until its instant stop. The surface of the metal roller sliding on the belt tears off its upper elastic layer, which creates the possibility of visually assessing the length l_{T}., during which the spindle deceleration occurs, and the "self-discharge" of the cotton bale occurs.

Earlier, we reported that the dimensions of the roller for the multi-ribbed belt were determined from the standpoint of ensuring the necessary spindle rotation speed in the working zone where the belt is wrapped around the roller from the outside. In the belt release zone, the belt's brake pads wrap around the roller from the inside, which changes the conditions of their coupling. This is because belts are designed to wrap around a pulley with their working surface. The optimal wedge profile is maintained when the pulley is wrapped. In our case, the working surface of the belt will be stretched, changing the wedge profile by becoming thinner, which will change the roller rolling process on the belts. It is known that the roller's rolling radius on external belts is determined as $r_p = R_b/(i-1)$, where R_b is the radius of the spindle drum, i is the gear ratio of the spindle angular velocity to the drum's angular velocity. In the drum release zone, the belts are stretched. Therefore, its roller rolling radius in the release zone is determined as $r_c = R_b/(i+1)$, which is smaller than in the working zone, i.e. always $r_c < r_p$. Taking this into account, it can be assumed that, firstly, the angular spindle rotation speed will decrease due to the change in the position of the belt's working side relative to the drum's center, i.e. due to the decrease in r_c. At the moment of the roller's contact with the internal belts, the braking process will begin due to the start of coupling with the belt. Therefore, it can be considered that a large negative angular acceleration will arise, which creates the possibility of losing the cotton bobbin's connection with the spindle surface. Therefore, it is considered that at the moment of contact with the internal belt, the coupling of the roller with the belt should be reduced. Our previous experiments showed that at the same tension, multi-ribbed belts in the working zone give almost 1.5 times greater traction force on the roller than conventional V-belts, i.e. the parameters of the multi-ribbed belt wedges provide greater coupling with the roller. Consequently, it can be considered that the roller's braking on the internal belts will occur more intensively, which will increase the negative angular acceleration of the spindle rotation compared to standard belts, increasing the probability of cotton slippage. Therefore, to ensure the spindle roller's braking during the spindle center's path of $l_{\mathrm{T}} = 60 - 70\ mm$, the coupling of the multi-ribbed belt with the spindle roller should be reduced.

The adhesion of the roller to the V-belt depends on many parameters of the profile of the wedges, including the contact area of the belt wedges with the grooves of the roller. To reduce adhesion, in our opinion, the tip of the wedges can be cut off, leaving only their wide lower base (figure 2).

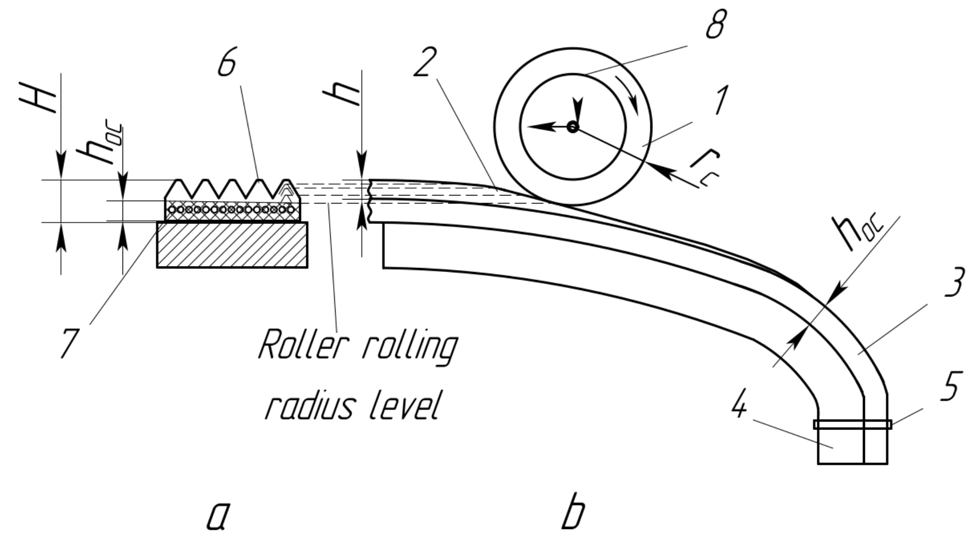

Figure 2. Diagram of cutting off the tip of the belt wedges: a- cross section of the belt; b- side view; H- total height of the wedge; h- height of the cut part of the wedge at the point of initial contact with the roller, h_{oc}- height of the remaining part of the belt wedges: 1- roller; 2- truncated part of the belt; 3- belt base, bent for attachment to the clamp; 4- metal clamp; 5- clamp; 6- cut-off tip of the belt wedges; 7- wide base of the wedges left; 8- geometric location of the grooves of the roller.

The wide base left without wedges should be long enough to bend it along the profile of the head part of the metal clamp and fasten it with a clamp 5. The belt is glued to the head part of the metal clamp, and the other end of the belt ends at point C (figure 1). The thin base of the belt can be bent up to point K and also secured with a clamp. This belt attachment prevents the belt from peeling off the base during roller contact. The clamping force of the belt by the reverse movement of the clamp to the rollers is adjusted by screw 7 in such a way that the roller is brought to position C without rotating or with minimum angular velocity. The belt is glued to the main part of the reverse rotation clamp, as this is enough to keep the belt in place until the end of the harvesting season. To guarantee the prevention of detachment, the flexible base of the belt end is also tightened to point K and secured with a clamp. The existing method of mounting the clamp to the drum frame is maintained as in the standard version.

3. Experiment results

An experiment was conducted on a stand with a single drum [2] to test the described stabilizer. Visual observations showed that the stabilizer provides spindle reversal along the path l_T. Due to the lack of technical capability to measure the nature of the change in angular velocity of the spindle at the head of the reverse drum, this limitation was made. Previously, we reported that the development of a device for non-contact measurement of spindle speed was completed. Therefore, we plan to conduct experiments with measuring the spindle speed in positions b, C, and d on the drum (figure 1).

4. Conclusions

The results of theoretical and experimental studies on improving the traction capabilities of the friction drive of vertical spindles of cotton harvesters allowed us to conclude that replacing conventional V-belts with poly-V-belts in this drive gave positive results. The traction force of the drive with poly-V-belts increases almost 1.5 times. Therefore, the angular speed of the spindles under high loads from cotton bushes will not decrease, the ability of the spindle to capture cotton will not deteriorate, which will increase the seasonal completeness of the machine's harvest by 3-4%.

Installation of poly-V-belts in the working zone of the drum requires structural changes in the drive and in the zone of cotton removal from the spindles. The above results of theoretical studies will make it possible to manufacture a drive that allows reversing the spindles with the necessary negative acceleration when braking it on the inner belts of the removal zone. Braking the spindle in a regulated mode will allow achieving optimal acceleration, when the completeness of cotton removal from the spindles will increase more fully by self-dumping, thereby reducing the process of "passing" cotton into the working zone. This allows increasing the proportion of cotton fed into the hopper without reducing the completeness of spindle harvest.

References

[1] Shoumarova M, Abdillayev T and Yusupov S 2022 *IOP Conf. Ser. Earth Environ. Sci.* **1076(1)** 012020 https://www.doi.org/10.1088/1755-1315/1076/1/012020
[2] Shoumarova M, Abdillayev T and Yusupov S 2022 *IOP Conf. Ser. Earth Environ. Sci.* **1076(1)** 012007 https://www.doi.org/10.1088/1755-1315/1076/1/012007
[3] 2017 *Tashkent Tractor Plant Instructions* (Tashkent: MX-1.8 Cotton picker)
[4] Jabbar O S 1977 *Theory of the cotton picker* (Toshkent: Science)
[5] Sablikov M V 1985 *Cotton picking machines* (Moscow: Agropromizdat)
[6] Rizaev A A 2017 *Research and creation of working bodies of a cotton picker with high efficiency* (Tashkent: Science)
[7] Shexovtsev V M 1965 *Investigation of the friction drive and the operation of the vertical pullers - spindle cotton pickers* (Tashkent)
[8] Mansurov U X 1986 *Basics of the technological process of cotton picking machines* (Tashkent)