PARAMETERS JUSTIFICATION OF PICKUP MECHANISM FOR FORAGE HARVESTER

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Abstract
In the article, new pickup mechanism for forage pickup choppers, balers, and forage harvesters has been suggested. In developing PIK-1.8 universal forage pickup chopper was installed a new pickup mechanism with high reliability. Results of theoretical and experimental research on pickup mechanism were given. Here, the main structure of the pickup mechanism was developed by the obtaining patent №9472 Republic of Kazakhstan andits main novelty is pickup fingers mounted to the reel rigidly, i.e., no treadmills, cranks, rollers, bearings and further without profiled attachments (as pickup reel of the company Krone). In this case, within the angle 180° of rotation of the fingers, i.e while lifting it through ring-rays its radius while turning to the angle $\Delta\varphi$ angle increases to a certain length ΔR. In the proposed pickup mechanism, the fingers will gradually move under the ring-rays. Here, when selecting the parameters of the pickup mechanism must take into account that the value of the angle γ between a finger and a tangent to the circle of the ring-rays must be more than or equal to 70°. As a result of laboratory and field tests were found that new pickup mechanism with the above parameters works well. In picking up and cutting dry mas the forage pickup cutter with new pick up mechanism worked with performance 6.0 - 9.0 t/h, in harvesting wet hay 3.2 - 5.0 t/h. During the testing of experimental model of the forage pickup cutter were checked theoretical determined parameters of pickup mechanism. Results of testing showed that all parameters have rational values. During laboratory and field tests the reliability of the new pick mechanism were proved.

Key words: pickup fingers, ring-rays, pickup reel, making hay, balers, harvesting alfalfa.

INTRODUCTION

Currently for picking up hay and grain mass conveyor and reel types balers are used (LISTOPAD ET AL., 1986; KARPENKO ET AL., 1983). In the design of existing forage harvesters pickup reel with controllable fingers and driven fingers are used (Fig. 1).

In designs of balers with control fingers on one side at the end of the tubular shaft are fitted cranks with rollers. During the technological process, these rollers rotate in the profiled treadmill. In this case, the profile of the treadmill provides finger rotation while leaving them under the ring -rays. In this case, on the horizontal section of the ring-rays, fingers almost in the vertical position omitted under the ring-rays. In this case, the capture of the stems by pickup fingers inside the ring-rays is excluded.

In the construction of the header also pickup reel with driven fingers are mounted, and it is intended to transfer the grain mass from the header to the inclined conveyor, which transfers the mass to the threshing drums hearer.

In the construction of combine, harvesters for picking the grain mass chain- slatted balers are used (Fig. 3). In design of combine harvesters, as well as in the pickup truck and chopper-spreader trailer conveyor type balers are used (LISTOPAD ET AL., 1986; ASTAFJEVS ET AL., 2011).

Last few years, due to the easy design paid attention to improve the design of reel pickup devices (PAT. KAZ, 2011; PAT.RU, 2009).

In these inventions providing the pickup reel with clamping device are offered, fastening of the fingers is perfected and also using the fingers of variable section are proposed. However, in these inventions a treadmill turning fingers are used.

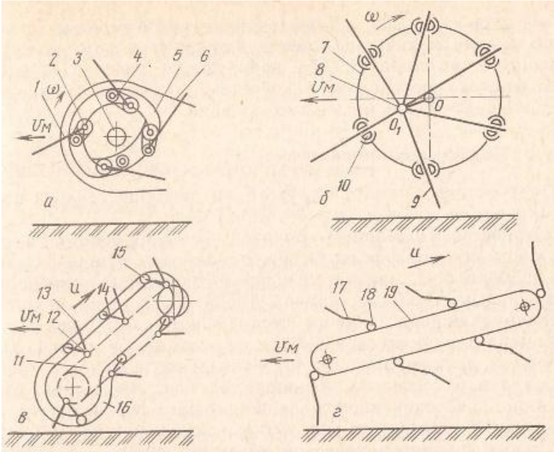

Fig. 1. – Scheme of the pickup devices

a – reel with controlled fingers; b – reel with driven fingers; *в* - chain-and-slat with controlled fingers; g – polotenno-slat; 1, 9, 13 and 17 - fingers; 2, 12 and 18 - tubular shaft; 3 - pickup shaft; 4 and 14 -cranks; 5 and 16 - track guide; 6 and 7 – the fixed and rotating housings; 8 – an eccentric shaft; 10 - peephole; 11 - chain; 15 - crank pulley; 19 - conveyor

The pickup reel that designed with controllable fingers has many fast wearing parts (roller, treadmill). In addition, the treadmill cannot be repaired and manufactured in economic conditions. Drum baler with a driven finger also has a complex structure and many wear parts.

Analysis of modern designs of pickup mechanisms shows that these balers have a complex structure and low maintainability details. All this reduces the reliability in terms of quality forage harvesting in agronomic terms.

In this regard, reliable operation provide pickers of the «Krone» company. These balers have not the treadmill rollers and cranks. This smooth movement of finger under the ring-rays carried out with the installation on the horizontal section of the ring- rays profiled attachment (Fig. 2).

Hence, it is clear that the world's leading firms phasing out from the production of balers with treadmills, i.e. development of balers designs implemented in the direction of simplification of design of modern of pickup mechanisms. The aim of study is development of a simple design pick mechanism which increased reliability of pickup work and productivity of the forage harvesters and grain harvesters.

Fig. 2. – Constant pickup device for many models of Krone Easy Flow

MATERIALS AND METHODS

Government Grant (State registration №0112PK01402) at LLP «Kazakh Research Institute of Mechanization and Electrification of Agriculture» supported development of forage pickup-cutter for preparing roughage and silage in 2012-2014.

For a theoretical justification of the parameters of the new pick mechanism applied methods of theoretical mechanics and construction of agricultural machinery.

Refinement of theoretical founded parameters exercised by conducting laboratory and field test on the forage pickup cutter with the proposed pickup mechanism.

New pickup mechanism without the treadmill, cranks, rollers and bearings (patent of RK №9472 and innovative patent RK №27286) is installed in the machine based on the zoo technical requirements for cutting roughage (17% to 22% of moisture content).

Hammers remade from steel (65G) plate 160 x 50 x 10 mm, they create a strong air flow, through the deflector can load crushed mass directly into vehicles. Cutting mechanism, which comprises a drum with knives and the shear bar. Depending on the required degree of cutting, on the drum it can be set 6, 9 or 18 knives. Shear bar has 6 working edges and it can be rearranged in the process of exploitation of harvester, which increases its service life.

Laboratory and field tests of experimental model of forage pickup-cutter equipped with a new pick-up mechanism were conducted using first, second and third crop alfalfa at the family farm that occupy 40 ha of fields, called "Zhaniko" Ili district of Almaty region. The crop was harvested and cut with forage pickup cutter which was mounted on the MTZ-80 (59.7 kW) and chopped material was conveyed into a trailer 2PTS-4. Stopwatch, tachometer, dynamometer and thermometer also were used during the experiment. Other devices were express moisture meter VLK-01, scales VLKT-500m, Express analyzer Infra Hast (for determination quality of chopped hay) of firm Foss.

15 samples (each weigh is about 60-80 g) of the chopped material were gathered to determine moisture content using the oven dry method (GOST 31640-2012). Another set of 15 samples was periodically gathered to determine the material practical size using GOST 27262-87.

The first experiment was conducted over five days, harvesting either first or second alfalfa crop. Second experiment was conducted over three days, harvesting either second or third alfalfa crop. All test were conducted with forage pickup cutter.

A subsequent experiment was conducted to determine the main technical parameters of the machine. In all the laboratory and field tests of the forage pickup cutter has been defined its power requirement by the torque meter. The value of torque and propeller shaft rotational speed were registrated on an oscillographic paper.

RESULTS AND DISCUSSION

Theoretical studies

In the proposed forage pickup cutter design pickup reel design were simplified and expanded operational capabilities of the machine.

In the proposed pickup mechanism (PATENT №9472 KAZ) fingers fixed inflexibly to the drum, and the ring-rays are made variable radius (PAT. KAZ№9472). Starting from a lower position to an angle Δφ of turning fingers, lower radius of ring-rays $R_i$and the next higher radius$R_{i+1}$is more than the lower radius for length ΔR (Fig. 3).

This gradual change in radius of ring rays provides a gradual withdrawal of fingers under the ring-rays. When choosing the length ΔR should be noted that the angle between the finger and a tangent to the circumference of the rings γ-slope should not be less than 70° (BASOI ET AL., 1977).

To determine the value of the angle γ considering the circuit shown in Fig. 4. For clearer explanation of the theoretical determination of the angle γ Fig. 4 shows separately the position of two adjacent rows of ring-rays.

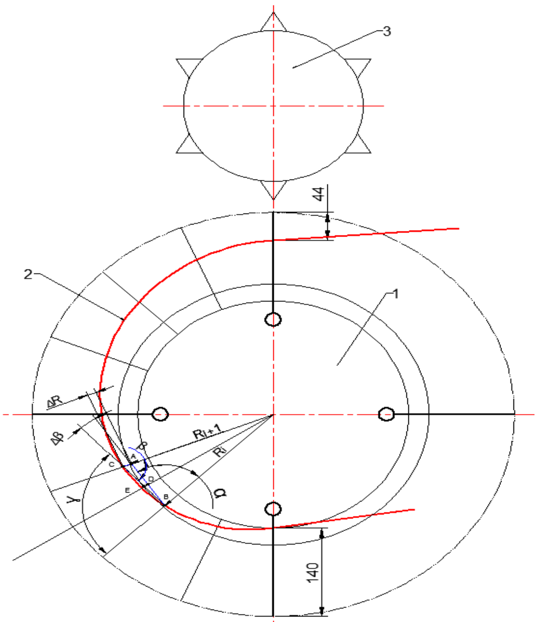

Fig. 3. – Scheme of the pickup mechanism
1- Pickup reel; 2 - ring-rays; 3- precompression reel

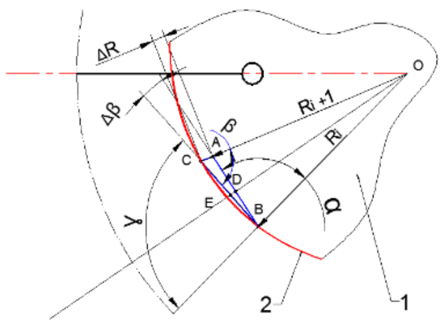

Fig. 4. – Diagram of changing radius of ring-rays for determination angle γ
1- Pickup reel; 2 ring-rays

Tab. 1. – Results of calculated data from telematics systems – John Deere

Number of tractors	Type of tractors	Operational hours (hrs)	Average values of fuel consumption CAN-BUS (l/hrs)	Average values of fuel consumption capacitance probe (l/hrs)	Difference of fuel consumption (l/hrs)
1	**John Deere 6630**	**1,028**	**7.3559**	**7.9606**	**0.6047**
2	John Deere 6630	1,158	11.594	12.377	0.783
3	John Deere 6630	1,257	8.807	9.986	1.179
4	John Deere 6630	1,023	7.247	7.776	0.529
5	John Deere 6630	1,268	10.58	11.392	0.812
6	John Deere 6530	1,087	11.698	12.61	0.912
7	John Deere 6530	1,587	8.837	9.903	1.066
8	John Deere 6530	1,698	8.356	8.929	0.573
9	John Deere 6430	1,147	12.546	13.259	0.713
10	John Deere 6430	1,158	10.458	11.431	0.973
11	John Deere 6430	1,236	7.549	8.623	1.074

* - measured and calculated data of fuel consumption (Fig. 2)

Here, due to the small value of the angle $\Delta\varphi$, the angle between the finger and a tangent to a circle of the ring-rays, which held between the radii R_i and R_{i+1}, approximately equal to the angle between the chord of the circle, which limited within the turning radius of the ring-rays to the angle $\Delta\varphi$, and by pickup finger, disposed in the middle chord (γ). Here the triangle BDE:

$$\gamma = 90 - \Delta\beta = 90 - \alpha - \beta = 90 - \left(\frac{180-\Delta\varphi}{2} - \beta\right) \qquad (1)$$

where$\Delta\beta$–the angle CDEwithinthechangingof radius-ring-raystoΔR;

α- from triangleAOB angleABO;

β – from triangleBOC angleBAO;

$\Delta\varphi$ – angle of turning ring-rays radii.

To calculate the value of the angle γ by the obtained expressions, it is necessary to determine the angle β. To determine the angle β consider the triangle COB. Fromthis triangle:

$$R_i^2 = R^2{}_{i+1} + CB^2 - 2R_{i+1} \cdot CB \cdot \cos\beta$$

Fromthis expression:

$$\cos\beta = \frac{R_{i+1}^2 + CB^2 - R_i^2}{2R_{i+1} \cdot CB} \qquad (2)$$

From the considered triangle COB:

$$CB^2 = R_i^2 + R_{i+1}^2 - 2R_i R_{i+1} \cos\Delta\varphi.$$

Inputting these values CB andCB^2 in the formula (2) we obtain an expression for determination an angle β.

$$\beta = \arccos\frac{R_{i+1} - R_i \cos\Delta\varphi}{\sqrt{R_i^2 + R_{i+1}^2 - 2R_i R_{i+1}\cos\Delta\varphi}} \qquad (3)$$

Inputting these values into the angle β in the formula (1) and taking into account that the limiting value of the angle γ must be at least 70°, for the determination of this angle, following expression is obtained:

$$\gamma = 90 - \left(\frac{180-\Delta\varphi}{2} - arccos\frac{R_{i+1} - R_i cos\Delta\varphi}{\sqrt{R_i^2 + R_{i+1}^2 - 2R_i R_{i+1} cos\Delta\varphi}}\right) \geq 70° (4)$$

Thus, according to this formula define a radius increment of ring-rays depending on the length of the longest dimension of fingers extending over the circumference of the rings-rays, given the fact that the angle between the circumference of the rings and finger-rays was not less than 70°, i.e. ensure the removal of stems capture by fingers inside the circle ring-rays.

The pickup reel’s finger is arranged so as its front surface extending beyond the circumference of the rings-rays when fingers are in the top of the ring-rays have a slope or bevel in the direction of the reel opposite rotation.

This solution provides an increase of the angle γ when stems of plant are in the upper part of the ring-rays, i.e. at the moment, when a maximum opportunity is appeared to pull stem by fingers inside the circle of ring-rays. This solution provides a reduction or elimination of force, which pulls the stem inside the circle of ring-rays.

To use this solution into practice, you can perform the front surface of the fingers end with a slope or it can be sharpened.

Production of ring-rays circle on the proposed form and fingers with a slope or bevel is not difficult. This eliminates the need for a mechanism that ensures turning of the fingers during rotation of reel, i.e. simplified production of the pickup reel and reduces the cost of its manufacture.

An example of the definition the variable radius circle of ring-rays.

During the work, the pickup fingers must pick up swath by ring-rays circle until the place, where the swath can catch precompression drum. It means the value of the angle when pickup fingers turning (from a short distance between the ends of the fingers and the ground, i.e. when they are arranged perpendicular to the ground) until full entrance into the ring-rays circle may be taken as in 225°.

In the pickup reel of existing machines when fingers are close to the ground the largest dimension of the length of the fingers, projecting over ring-rays is equal to 120-140 mm (BASOI ET AL., 1977).

, therefore, will take the value of the maximum size of the length of fingers, extending over the rings-rays circle to 140 mm.

As shown in Fig. 3, the operating angle of rotation of the pickup reel fingers weredivided into 8 parts, i.e. Δφ=22,5°. Thus $\Delta R = 12$ mm.

If use prepared serial spring as a pickup fingers and install them on the axis, as shown in Fig. 14, then we can take the value of the minimum radius ring-rays to 120 mm, and the radius of the fingers – 260 mm, i.e. $R_i = 120$ mm, $R_{i+1} = 132$ mm, $\Delta R = 12$ mm, $\Delta\varphi = 22{,}5^0$.

Now we determine the value of the angle between the chord of the circle, limited within the turning radius of the rings-rays to the angle $\Delta\varphi$ and the pickup finger, placed in the middle of the chord.

$$\gamma = 90 - \left(\frac{180-\Delta\varphi}{2} - arccos\frac{R_{i+1} - R_i cos\Delta\varphi}{\sqrt{R_i^2 + R_{i+1}^2 - 2R_iR_{i+1}cos\Delta\varphi}}\right) \geq 70° = 90 - \left(\frac{180-22{,}5}{2} - arccos\frac{132 - 120\cdot 0{,}9239}{\sqrt{120^2+132^2-2\cdot 120\cdot 132\cdot 0{,}9239}}\right) = 76{,}5°$$

Thus, according to the calculation of the angle γ is more than 70°, i.e., the value of the radius increment of the ring-rays circle is determined correctly. If the angle γ less than 70°, it is necessary to increase the value of diameters of pickup reel and ring-rays.

From these calculations, it is known that the diameter of the Pickup reel – 520 mm, minimum radius – 120 mm and a maximum radius of ring-rays – 216 mm, ΔR -12 mm, γ - 76,5°, in the vertical position of the fingers, the maximum length of the projecting part of fingers under the ring-rays – 140 mm and the minimum length of the fingers protruding under the ring-rays – 44 mm.

Pickup mechanism with above parameters is set to forage pickup chopper PIC-1.8. Laboratory and field tests of experimental model of pickup-chopper equipped with a new pick-up mechanism have been carried out in the family farm "Zhaniko", Ili district of Almaty region. As part of this machine developed new pickup mechanism showed a highly reliable operation, and not observed process shutdown due to a failure of the pickup mechanism.

When picking up and chopping herbs with humidity 18-20% pickup chopper has a capacity - 6.0- 9.0 t/h, and it provides pickup andgrinding of roughage in humidity of 45-55% for making silage. In making silage its performance is in the range of 3.2 - 5.0 t/h (ABILZHANULY ET AL., 2014).

Fig. 5. – Forage pickup chopper PIK-1,8 with new pickup mechanism (Pickup and cuttinghay with moistur econtent 18-20%)

Currently, the pickup mechanism is mounted on a prototype square baler PT-160, and there is an interest to this pickup mechanism of "Bobruiskagromash" (Republic of Belarus), which develops baler PT-165. The technical novelty of the pick mechanism is proved by obtaining a patent Republic of Kazakhstan №9472 «Pickup-chopper for cattle" and innovative patent RK №24471 «Pickup reel for harvesting agricultural machinery» (PAT. KAZ№19961;PAT. KAZ№24471).

CONCLUSIONS

1. As a result of theoretical research the radius increment of ring-rays is determined, depending on the longest length dimension of fingers extending over the rings-rays circle, given the fact that the angle between the rings-rays circle rings and fingers was less than 70°, i.e. ensure the removal of stems capture by fingers inside ring-rays circle.

According to the calculation of the angle γ more than 70°, i.e., correctly determined the value increment of the radius circle ring-rays. If the angle γ less than 70°, it is necessary to increase the value of diameter of pickup reel and ring-rays.

2. As a result of laboratory and field tests were found that the pickup mechanism with the above parameters works well, and there was not stopping the technological process due to a failure of the pickup mechanism.In picking up and cutting dry mas the forage pickup cutter with new pick up mechanism worked with performance 6.0 - 9.0 t/h, in harvesting wet hay 3.2 - 5.0 t/h.

3. In testing an experimental sample of forage pickup chopper were tested theoretically certain parameters of the picking mechanism. Test results showed that all the parameters of the new pick mechanism have rational values. Also proved the reliability of the pickup mechanism during laboratory and field tests.

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REFERENCES

1. BASOI, E.S., VERNIAIEV, O.V., SMIRNOV, P.P., SULTAN SHAH, E.G.: Theory, design and calculation of agricultural machinery: Textbook for higher educational institutions of agricultural engineering. p. 568. Moscow. Kausr. 1977.
2. LISTOPAD, G.E., DEMIDOV, G.K.: Agricultural and reclamation machines: Textbooks and learning manuals for Executive. p. 688. Moscow. Agropromizdat, 1986.
3. KARPENKO, A.H., KHALANSKY, V.M.: Agricultural machinery: Textbooks and teaching aids for higher educational institutions. 495 p. Moscow. Kolos, 1983.
4. ASTAFJEVS V.L., BOBKOV S.I.: Parameters pneumatic pickup-truck. Tractors and farm machinery. №7. Moscow.185, 2011: 10-11.
5. PAT. KAZ №25513 Republic of Kazakhstan A01F 29/00, A01D 87/10. Trailed chopper-spreader rolls of straw / Laptev NV, SvetlakovAY.; patent RSE "Kostanay State University im.A.Baytursynova" MES. - №2011 / 0239.1; appl. 11.03.11; publ. 15.03.12, Bul. No. 3.
6. PAT. RU №2438292 C1 Russian Federation, A01D 89/00. Drum Baler / Kopchenov A. A .; patent FSEIHPE "Chelyabinsk State Academy of Agricultural Engineering". - №2010144730 / 02; appl. 01.11.10; publ. 10.01.12, Bul. №1.
7. PAT. RU №2420946 Russian Federation, A01D 89/00. Gatherer device for harvesting agricultural / Getty Christophe Lionel Haas, Fabien Mey, Thierry Bonhomme; patent Uzyn CLAAS France SAS (FR). - №2006140852 / 21; appl. 27.05.08; publ. 20.06.2011, Bull. №17.
8. PAT. RU№125018, A01D. Node fastening fingers drum picker. / KOPCHENOV A. A.; patentees FSEIHPE "Chelyabinsk State Academy of Agricultural Engineering". - № 000000; appl. 19.10.11; publ. 02.27.13, Bul. №6.
9. PAT. EP2342967 A1 Germany, A01D 89/00. Pick-protected winding / FreitagAloys; patent FreitagAloys. - №EP20110000016; appl. 03.01.11; publ. 13.07.11.
10. PAT. RU №2409018 C2 Russian Federation, A01D 89/00. Pick drum stems of crops / Smirnov N.A, Sokolov VN, Lobachyov AA, Smirnov B.; patent FSEIHPE "Kostroma State Agricultural Academy." - №2009108868 / 21; appl. 10.03.09; publ. 20.01.11, Bul. №2.

11. PAT. KAZ№9472, MPK6 AO1D 89/00. Pick-cutter feed for livestock / T. ABILZHANULY SEITBEKOV, L., RZALIEV, AS, ZHORTUYLOV, O.ZH. The applicant and patentee of State Enterprise "Kazakh Research Institute of Mechanization and Electrification of Agriculture» - № 990408.1; appl. 07.04.99 was published. 16.10.2000; Bull. Number 10. - P.75.
12. ABILZHANULY, T., ABILZHANOV, D.T: Development of a universal feed pickup cutter. Agricultural Science - Agricultural Production in Siberia, Mongolia, Kazakhstan and Bulgaria. In: Proceedings of XVII International Scientific and Practical conference. 13 November 2014, pp.133-135, Novosibirsk.
13. ABILZHANULY, T., ABILZHANOV, D.T.: Determination of the air flow velocity in the deflector of forage pick up cutter. In: Proceedings of II International Scientific and Technical Conference "Agricultural machinery".2014.Varna, Bulgaria,
14. ABILZHANULY, T.: Machines other agricultural formations: a manual for agricultural engineering specialties of higher educational institutions. Publishers S.Seifullin, Astana. 200. 2007 (In-rus).
15. PAT. KAZ№19961, A01D89100. Crushing and cleaning device for cattle feed / Abilzhanuly T. 0318.1., 16.03.2006. Publ. 27.06.2007.
16. PAT. KAZ№24471, A01D 89/00. Drum pick for harvesting agricultural machines / Abilzhanuly T., Zhortuylov, O., Evtifeev, A.G., Alekseek, A.A. Soldatov V.T., Bekenov C.U., Smagulov T.A. The applicant and the patentee; "Kazakh Research Institute of Mechanization and Electrification of Agriculture» .- №2010 / 1371.1; appl. 08.11.2010 of Publ. 15.09.2011.
17. PAT. KAZ №27286, A01D 89/00 Pick for forage and grain harvesters / Abilzhanuly T., Zhortuylov O, Uteshev V.L., Abilzhanov D.T. The applicant and the patentee: "Kazakh Research Institute of Mechanization and Electrification of Agriculture»- №2012 / 1113.1; appl. 24.10.2012 r .; publ. 09/16/2013.

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