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OF THE REPUBLIC OF KAZAKHSTAN

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RESEARCH OF STRIPPER MECHANISMS FOR HARVESTING GRAIN CROPS IN KAZAKHSTAN

Abstract. This article describes harvest of crops by stripping heads. This allows us to radically change the harvester technology.

Key words: combine harvester, model, level use.

Annually about 2.5 billion tons of grain are produced in the world, 1.5 billion tonsof which are cereals, 720 million tons – wheat, and 490 million tons – rice. Grain production in Kazakhstan is one of the most profitable and export-oriented agricultural sectors. In record years Kazakhstan produced up to 34 mln tons, and currently produces from 16 to 20 mln tons. This providesus not only food, but also creates a stable livestock feed base that will enable to reduce imports of meat and dairy products. In general, for the countries that are major exporters of grain the production of 2 tons of grain per capita is considered to be the self-sufficiency level. In Soviet times, Kazakhstan met these criteria [1].

In addition, we should not lose sight of such specific area of Kazakhstan's grain production as rice cultivation. Annually, more than 50 quintals of rice per hectare on average are harvested, gross harvest amounts to 423 thou. tons of rice.

Therefore, for Kazakhstan, which is essentially the republic of grain, searching and implementation of effective technologies and facilities is a matter of food security and the competitiveness of the country's agricultural sector. What innovations doesthis sector have?

In XXI century, new machines and technologies of harvesting grain and tailings straw and chaff, as well as methods of deep processing of straw emerged. While the value of grain was obvious, straw and chaff were widely used. There is another equally important scope of application of straw, which is especially topical in Kazakhstan – it is leaving the long stubble on the field after stripping heads. In the United States, Canada and Australia, where "no-tilltechnology" is more widely used, the long stubble is very important. It facilitates both the accumulation of moisture and soil conservation against wind erosion [2].

Taking into account the fact that straw yield exceeds 1.5-3 times grain yield by weight you can imagine how much straw goes through threshing and separating units of a(grain)combine, mixing straw and grain, and then a lot of effort is put to separate them. Large power expended during combine harvesting is caused, first of all, by the energy of deformation of straw and the dimensions of combine are determined by the size of a straw walker and a screen-type separator, which separates wheat from the chaff. This paradoxical process has always drawn the attention of engineers and inventors to the elimination of this obvious contradiction – "why to mow and mix grain and straw, which create a number of problems - crop losses, time and energy consumption – wouldn't it be more sensible to harvest them separately?". The question is obvious, but how to do that?

To solve this problem, we proposed a comb actuator with an active rotor (figure 1).

Its main working element is a rotor (figure 1) which consists of a pipe 1 which along the outside diameter chute boards 2 were evenly and radially mounted, which are rigidly connected to each other by a disk 3 coaxial to a rotor from one end.

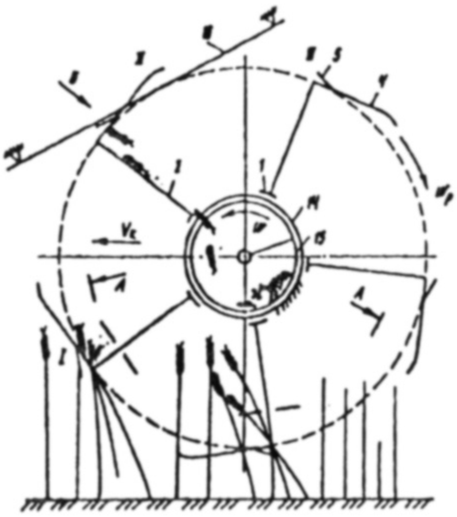

Figure 1 – A stripper machine for harvesting grain crops

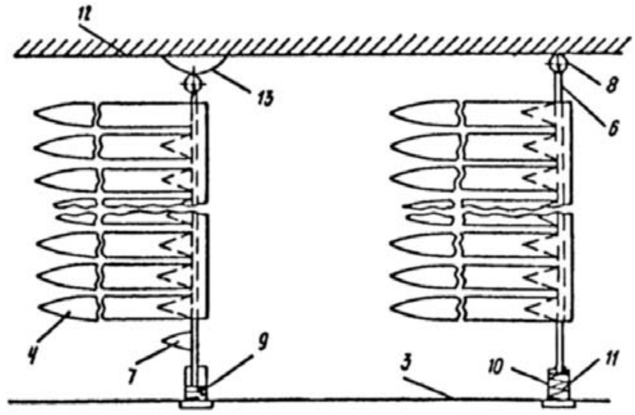

Figure 2

The device for collecting grain crops at the base works as follows: at the position I (Figure 2), the base of a comb 4 is at the level of height of heads of the highest plants. At the same time heads of plants with lower height,which fell into an operating zone of the comb earlier, are separated from their stalks, and some of them are even pulled with a stalk and a rootstock out of the soil, if the force required to pull heads from stalks is greater than the bonding strength between stalks and the soil having enough moisture. At this point, a roller 8, the axis of which rotates together with the rotor, rolls to a projection 13 mounted on a stationary disc 12 relative to the frame (Figure 2), and then a cutting unit starts, i.e. heads collected by a comb are separated from stalks, which are pulled out of the soil. After the roller 8 will roll off the ledge 13, a cutting blade under the action of a pressure spring 11 returns to its original state [3].

In the position II, the comb 4 interacts with a mechanism which cleans it. Entrapment of a wisp of heads cut between the cogs of the comb and separate tops of the individual weeds are pushed out of its slots and along the chute board 2 enter the corresponding window – slot, tube 1, which at this moment matches with the longitudinal profile on the cylinder 14. Thus, the collected mass of heads enters an operating zone of an auger conveyor 15 which removes it off the rotor, thus providing an opportunity to further supply of the mass to the threshing unit or a delivery cart.

Then the comb 4 reaches the position III in which the base of its chute board 2 passes completely the width of the longitudinal slot in the cylinder 14 and the comb cleaned from the mass is ready again to perform stripping heads, and the cycle repeats. Provided that the level of height of the rotor can be adjusted depending on the surface of the field, as well as the position of the projection 13 on the board 12 can be made on the move of the machine.

The radius of a rotor of the stripping machine is chosen according to the conditions of shock-free entry of a reel bar to standing crops and stripping all layers of heads from the minimum height - h_{min} to the maximum height - h_{max}. Given that the height distribution is subject to the normal law, we have:

$$R = \frac{V_M}{\omega} + 6\sigma_h^2$$

where V_M - the forward velocity of a machine, m/s; ω - the angular rate of a reel, sec^{-1}; σ_h^2 - dispersion of the height distribution of standing crops.

The reel height above the ground is determined by the following expression:

$$h_0 = h_{\min} + \frac{V_M}{\omega} + 6\sigma_h^2$$

The number of combs was chosen according to the conditions of stripping all standing crops along the run with no gaps (figure 3), i.e, a portion,being stripped by the comb should strictly follow the crop conditions, stripped by the previous comb. In the figure we see that the top "в" comes to the point B within $\frac{\pi}{2\omega}$.

The equations of motion of the front part and end of fingers are described as follows:

For the front part of fingers $\begin{cases} x_B = \sqrt{R^2 + L^2} \cdot \cos\omega \cdot t \\ y_B = V_M \cdot t + \sqrt{R^2 + L^2} \cdot \sin\omega \cdot t \end{cases}$

where R - the radius of a circle of the described finger; L_1 - the length of the finger of a comb.

For the end of fingers $\begin{cases} x_C = R\cos\cdot(\omega \cdot t - \gamma - \alpha) \\ y_C = V_M \cdot t + R\sin(\omega \cdot t - \gamma - \alpha) \end{cases}$

when $\gamma = arctg\frac{L_1}{R}$

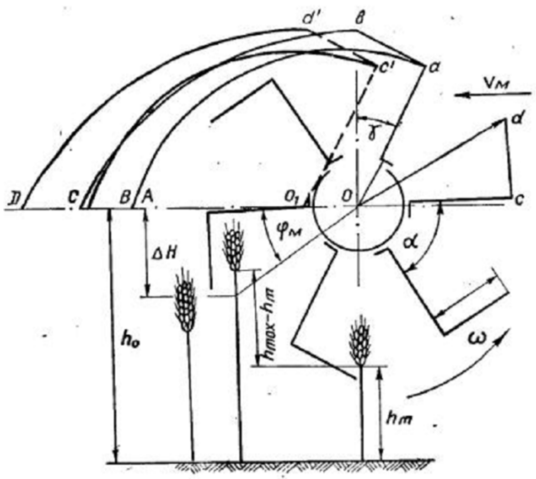

Figure 3 – For justification of the number of combs of a stripper header

Obviously, it is necessary to have the end of the following finger hit a passing point of the horizontal by the end of the previous one, i.e. $y_B = y_C$. From which the central angle per one comb will be equal to:

$$\alpha = \frac{\omega \cdot R}{V_M} \cdot \left(\frac{1}{\cos\gamma} - 1\right) - \gamma .$$

The number of combs is determined by the following formula:

$$m = \frac{2\pi}{\alpha} = \frac{2\pi}{\frac{\omega R}{V_M}\left(\frac{\sqrt{R^2 + L_1^2}}{R} - 1\right) - arctg\frac{L_1}{R}}$$

In the upward movement of the combs with heads a stalk, being strained can be pulled out of the soil with its root or break off at the base of the head. The latter is more desirable. The determination of the the pullout strength of the head from the stalk and the probability of pulling the root of a plant out of the soil was carried out in field experiments [1-3].

The experiments have shown that the probability of pulling the stalk out of the soil in the south of Kazakhstan is negligibly small compared with the probability of pulling a head from a stalk. The average value of the pullout strength of the head from the stalk for any length of stalks is shown as an empirical equation in figure 4. This regression is well approximated by the equation:

$$P_C = 7{,}836l - 186{,}318 - \frac{91}{l}$$

when the correlation ratio is $\theta = 0{,}984$, which defines between the pullout strength and the length of the stalk.

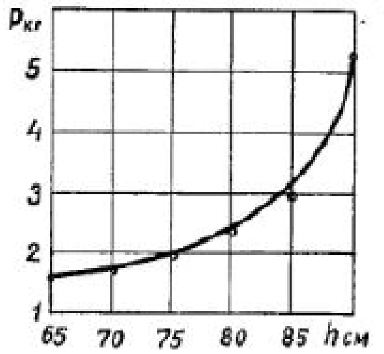

Figure 4 – The pullout strength of a head from a stalk depending on its length

In our scheme of a rotor a whole family of harvesters is created: the UK, Ukraine, Russia and Argentina. The stripper headers “Ozon” (Russia), “Slavyanka” (Ukraine) and “Shelbourne Reynolds” (United Kingdom), conveyor type ZHONTU-6 (Zernograd) were created.

The main difference of all models introduced is the amount of stripper rotors (drums), but the principle of works of all headers is the same.

Twin-rotor stripper headers are more multifunctional than single-rotor ones, they are suitable for harvesting both high-yielding and partially weedy crops, but its main problem is high-complexity.

In Russia, twin-rotor harvesters are produced by “Penzmash” (OZON-4) and Krasnoyarsk Combine Harvester Plant (OKD-4). Implementation scheme of the model OZON-4 is almost similar to the structure of MON of Melitopol and harvesters under the brand OKD-4 in many ways are similar to Ukrainian Slavyanka (UAS-7) produced by “Agro-Soyuz” Production Company, designed for harvesting cereals and grass seed by direct harvesting.

In 1988 the first tests of the industrial prototype of Melitopol harvester MON-4.0 began, which took place during harvesting winter wheat. In the design of the machine two stripping rotors rotating towards each are used, each of which had six rows of stripping combs. The first rotor partly stripped and supplied plants to the slot between the rotors by means of the second rotor final stripping of heads was performed. Then a stripped mass entered a feed chamber, where with the help of an auger fed onto a conveyor of a feed elevator, and then to a combine’s thresher.

MON-4.0 tests were carried out at the end of the harvesting period when standing crops were characterized by increased infestation (14.4%) and high degree of lodging (42.1-84.8%). The operating speed during harvesting the areas with a degree of lodging of 42.1% was 3.3-6.3 km/h on heavier areas (a degree of lodging 84.8%) - 1.6 km / h. Thus the total loss of grains at all speeds were 0.89-1.87%, the bulk of which was accounted for losses of free grains (0.78-1.20%), to a lesser extent – for stripped heads (0.09-92%), and very small share – for losses of non-stripped heads (0.01-0.02%) [1-3].

The history of the famous stripper header Shelbourne Reynolds dates from the first half of the 80s and directly relates to the emergence of a twin-rotor stripping unit, developed by the British National Institute for Agricultural Engineering (NIAE). The structure of the first machine of NIAE only vaguely resembled the structure of the stripping module of MON. But, unlike the Melitopol harvester stripping rotors of the British analogue it has different diameters, and in the structure of the front part of the body (a ruler hood) adjustment vertically and horizontally depending on the state of standing crops was provided for. Furthermore, at the bottom of a feed chamber there was a belt conveyor, which fed a stripped mass to an auger.

In the course of the experiments NIAE experts left behind the twin-rotor scheme. Over the next year they developed and successfully tested a new, more compact version of a stripper with a single rotor equipped with eight rows of combs with plastic fingers. In the design of the new machine there were an adjustable hood and a conveyor belt. The British company Shelbourne Reynolds Engineering Ltd was involved in the manufacture of these machines. Since 1990 it has mastered serial production of SR series multifunctional single-rotor stripper headers. In the new models of stripper headers Shelbourne Reynolds the rotor diameter is increased to 610 mm. The belt drive system allows to adjust infinitely the rotation speed of the rotor within 440-770 rounds per min directly from a combine's cab. The grasp width of CVS range grain harvesters is 5.4-9.6 m, and wide-cut models (7.2-9.6 m) are shifted to the right for compensation of the weight of the heavier left edge, thus attaining a balanced load distribution on harvester wheels[1-3].

In figure 5 "Shelbourne Reynolds" you can see that the primary working unit is a stripper rotor having eight rows of combs rotating in the direction opposite to a conventional reel. The rotation speed of the rotor with combs adjustable from an operator cab of combine harvesters is in the range from 470 to 775 rounds/min. The principle of work of stripper headers is as follows. The stalks with heads are deflected by a shield located in front of the rotor, this allows all heads to be almost at the same level. Then, this layer of grain mass is combed by a comb stripping heads from stalks.

We have studied this process and it has been revealed that the bonding strength between a head and a stalk is significantly less than the bonding strength between a stalk and the soil, which guarantees breaking off heads from stalks. At such intensity of stripping threshing of heads occurs simultaneously, and 80% of grains are threshed by a rotor, which together with cavings are fed to a conveyor auger, and then to a feed elevator of a combine harvester or to a trailer for transportation to the station.

Figure 5 – A header Shelbourne for stripping heads of grain crops

The next stage of revival of harvesters of a twin-rotor scheme was in the early 2000s. Since 2002, "UkrAgroservis" in Kharkov have been producing these stripping machines. A few years later a prototype of the header Slavyanka UAS-5, and then Slavyanka UAS-7 were created. Compared with its predecessors (MON) Slavyanka UAS type harvesters have a slightly different design.

Figure 6 – Modern stripper header "Slavyanka UAS"

Production tests over stripper headers in the United States, Canada, Europe and Russia have shown the possibility, even with the grasp width of 12.6 meters to increase the movement speed of the harvester 2 times up to 6 - 10 km/h, which, in turn, reduces the time of harvesting and decreases grain losses caused by shedding, and also reduces a combine fleet [3].

However, it should be borne in mind that these stripping headers were evaluated and tested on unweedy standing crops of western countries. Only testing can show how this header will work in Kazakhstan's weedy crops.

Stripping headers began to enter Kazakhstan 10 years ago, these were devices of the British company "Shelbourne" not adapted to our conditions, to our fragile, lodged grain crops. They have not proven themselves as efficient, as they were designed for harvesting wet crops in England.

"Penzmash" OJSC obtained the test results of the stripper type mounted harvester "Ozon", carried out by the Kazakh Scientific Research Institute of Mechanization and Electrification. The stripper type mounted harvester developed by "Penzmash" is aggregated with domestic and foreign harvesters. This header has several design versions depending on the type of a combine.

This mounted equipment allows you to harvest crops, seed pods of plants, are more efficient than traditional headers two or more times, energy saving is up to 45%, in addition, this method allows to harvest lodged, limped and heavily weedy crops, as well as to harvest at high humidity (up to 30% i.e yellowing). The operating principle of stripper type mounted harvesters, serially produced at the plant of "Penzmash" OJSC is based on threshing through stripping by combs, located on a harvester's reel. At the same time the plant stalk is grasped by combs and extends through the slot between them, releasing grain (seed). The grain mass up to 80% consisting of free grains under the effect of inertia and the airflow moves to a feed chamber, which delivers it to the harvester's threshing unit for threshing and separation.

Figure 7 – Testing Ozon in Kazakhstan, Kostanay

According to tests carried out in many farms of Russia and Kazakhstan structural changes have been made allowing to reduce the loss for up to 1% (for North Kazakhstan), which is confirmed by the results of tests carried out by the Kazakh Scientific Research Institute of Mechanization and Electrification of Agriculture. According to the test results, the header "Ozone" fits the technology and structure of machines for harvesting grain crops in the conditions of Northern Kazakhstan, where in areas of the steppe zone the accumulation of winter moisture due to high crop residues occurs. And also a decrease in fuel consumption up to 386 grams per quintal was confirmed.

Wet, lodged, matted and solid paddy straw, containing a large amount of silicon did not enter the threshing unit of a combine harvester, greatly facilitating its operation and reducing power consumption. The main difference of a paddy combine harvester and a stripping harvester is the form of the working slot between fingers that have spatial stiffening ribs, a more powerful mechanism of a rotor and a drive motor. Given that the humidity of straw in rice fields, usually exceeds several times the humidity of grain and harvesting can be started much earlier, thus preventing the losses by shedding as well as clogging of an auger, a feed chamber and a threshing drum by long, strong straw part of rice crops.

This headers can be mounted to almost all models of harvesters. The Russian and Belarusian combines need a special adapter for mounting strippers.

Moreover, taking into account the fact that the load on the separation part increases and a straw walker remains unloaded there is a need for another technological design. For example, instead of the straw walker there should be an extra screen separator, the power and geometric dimensions of a threshing drum should be reduced. So, it will be a completely different combine harvester [1-3].

Conclusion.

1. One of the most revolutionary trends that could radically change the technology of harvesting of grain crops, is stripping heads at the base. This method of harvesting makes it possible to radically improve the performance of combine harvesters, reduce grain losses during harvesting.

2. There is another equally importantscope of the use of straw, which is especially relevant in Kazakhstan - it is leaving long stubbles on the field after stripping heads for "no-till technology". It facilitates both the accumulation of moisture and soil conservation against wind erosion.

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А. Ш. Джамбуршин, Г. Д. Турымбетова

Қазақ ұлттық аграрлық университеті, Алматы, Қазақстан

ҚАЗАҚСТАНДАҒЫ ДӘНДІ ДАҚЫЛДАРДЫ ЖИНАУ ҮШІН СТРИППЕР МЕХАНИЗМДЕРІН ЗЕРТТЕУ

Түйін сөздер: дәнді дақыл жинау комбайн, модель, қолдану деңгейі.

Аннотация. Мақалада күрішті сабақтарын түбінен тарамдау әдіс бойынша күріш жинаудың технологиясы суреттелген, ол комбайндар технологиясын түбегейлі өзгертуге мүмкіндік береді.

А. Ш. Джамбуршин, Г. Д. Турымбетова

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ИССЛЕДОВАНИЕ СТРИППЕРНЫХ МЕХАНИЗМОВ ДЛЯ УБОРКИ ЗЕРНОВЫХ КУЛЬТУР В КАЗАХСТАНЕ

Аннотация. В статье описывается уборка зерновых культур-посредством очеса колосьев на корню, что позволяет радикально изменить комбайновые технологии

Ключевые слова: зерноуборочный комбайн, модель, уровень использования.

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