RESEARCH ARTICLE | OCTOBER 13 2022

Justification for changing the geometry of the spring pin pickup surface of the grain crop pickup

I. I. Ognev; M. V. Pyataev; A. P. Zyryanov; I. G. Ognev

AIP Conf. Proc. 2503, 030001 (2022)
https://doi.org/10.1063/5.0099719

Justification for Changing the Geometry of the Spring Pin Pickup Surface of the Grain Crop Pickup

I.I. Ognev[1, a)], M.V. Pyataev[2, b)], A.P. Zyryanov[2, c)], and I.G. Ognev[1]

[1]*UrFU named after the first President of Russia B.N. Yeltsin*, *Yekaterinburg, Russia*
[2]*South Ural State Agrarian University*, *Chelyabinsk, Russia*

a) Corresponding author: ognev.i.i@yandex.ru
b) 555maxim@mail.ru
c) zap174@list.ru.

Abstract. The issue of reducing grain losses during separate harvesting when using a conveyor pickup is a scientific and an applied problem. In this work, the obtained results of industrial research of a conveyor pickup equipped with a spring pin with an annular coil on the pickup surface were investigated. In this article, the theoretical prerequisites for changing the geometry of the pickup surface of the spring pin of the grain crop pickup were considered, as well as options for changing the geometry of the pickup surface of the spring pins of the grain crop pickup.

INTRODUCTION

Today, food security issues are important both within the framework of any state and in a global sense. In this regard, the importance of agricultural sector is obvious [1].

One of the main tasks of the agro-industrial complex is to provide the population with bread, and for that cultivation of grain crops is carried out. An important component of crop production is mechanized harvesting process [1].

As you know, the main types of grain harvesting include direct combining and separate harvesting - mowing grain mass into swaths using windrowers and subsequent ripening, picking up by a conveyor pickup and threshing [1, 2].

For the Southern Urals and a number of other territories with similar natural and climatic conditions, in most cases, it is advisable to use a separate technology. It provides faster and more uniform grain ripening, enables to start and finish harvesting earlier, reduces losses and increases harvest, ensures dry and clean grain. The success of separate harvesting depends largely on the selection quality of grain mass swaths by the conveyor pickup of grain crops [3, 4, 5]

OBJECT OF RESEARCH

The object of this research is the pickup surface of the spring pin of the conveyor belt of a grain crop pickup.

RESEARCH RESULTS

In the course of technological process of picking up a grain mass swath, the combine harvester selects the speed of the conveyor belt in such a way that the grain mass is not unloaded in front of the pickup, but is carried by the ends of the spring pins. Based on this position, the speed of the conveyor belt ($V_{тр}$) must be equal to the forward speed of the combine ($V_к$). Then the number of revolutions (c^{-1}) of the conveyor belt shaft can be found from expression (1) [5]

$$n_B = \frac{60 \cdot V_K}{\pi \cdot D_B}, \tag{1}$$

International Conference on Modern Trends in Manufacturing Technologies and Equipment 2021
AIP Conf. Proc. 2503, 030001-1–030001-6; https://doi.org/10.1063/5.0099719
Published by AIP Publishing. 978-0-7354-4221-4/$30.00

where $\boldsymbol{V_K}$ – forward speed of the combine, m/s;

D_B – initial diameter of the pickup conveyor belt shaft, m.

At the same time, the number of meetings of the spring pins (Z_{Π}) with the grain mass swath per second is equal to

$$Z_{\Pi} = i \cdot \frac{V_{TP}}{2 \cdot \pi \cdot R_{\Pi}}, \tag{2}$$

where i – number of rows of spring pins on the pickup conveyor belt,

i = 20 pcs.;

V_{TP} – circumferential speed of the conveyor belt, m/s;

R_{Π} – radius of the end of the pickup spring pin, m

Interaction of the pickup spring pin with the grain mass swath is shown in Fig. 1.:

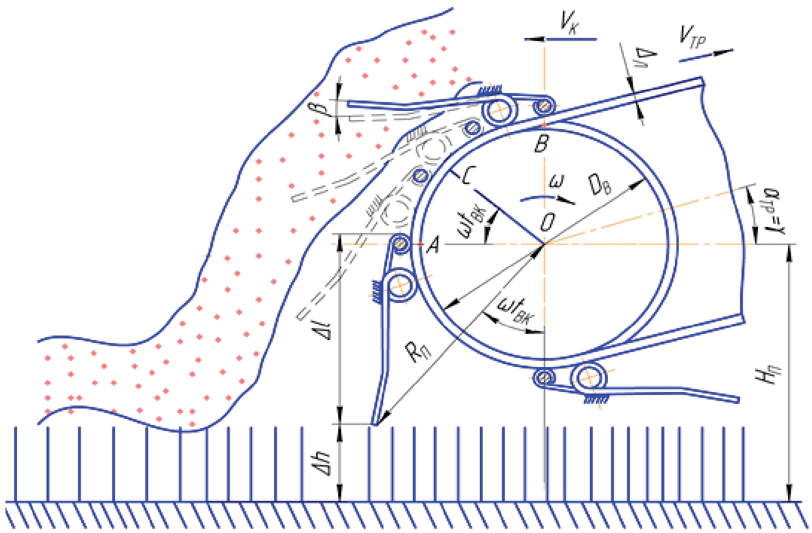

FIGURE 1. Scheme of interaction of the pickup spring pin of the pickup conveyor belt with the grain mass swath [5]

where R_{Π} – radius of the end of the pickup spring pin, m; Δl – length of the spring pin protruding above the pickup conveyor belt, m; D_B – diameter of the shaft of the pickup conveyor belt, m; H_{Π} – height of the conveyor belt shaft above the field surface, m; Z_{Π} – number of spring pin rows, pcs; S – circular pitch of the spring pins, m; β – angle of inclination of the spring pin from its radial location, degrees; α_T – angle of inclination of the conveyor belt, degrees; n_B – frequency of rotation of the conveyor belt shaft, min^{-1}; V_{Π} – pickup working speed, m/s, $V_{\Pi} = V_K$; $V_{K\Pi}$ – speed of the end of the spring pin, m/s; b – spacing of the row spring pins across the pickup width, b = 0.02 m; B – pickup width, m; Δh – minimum clearance between the end of the pin and the surface of the field.

During one revolution of the conveyor belt, two periods of operation can be distinguished:

1) the period of interaction of the spring pin with the grain mass swath. In this case, the plant mass is moved by a spring pin in a vertical plane, that is, it rises and then is moved by the conveyor belt until the spring pin hides under the lower part of the conveyor belt;

2) the idle movement of the spring pin, which consists of going under the lower part of the conveyor belt until it re-meets the grain mass swath.

In this case, the trajectory of the absolute movement of the end of the spring pin can be described in parametric form by expression (3) [6]

$$\boldsymbol{x = V_0 \cdot t + R \cdot \sin \omega t,}$$
$$\boldsymbol{y = H_{\Pi} - R \cdot \cos \omega t.} \tag{3}$$

The speed of the end of the spring pin in the area of its rotation (points A and B) is determined by the following expression:

$$\dot{x} = V_{\Pi} + \omega \cdot R \cdot \cos \quad \omega t,$$
$$\dot{y} = \omega \cdot R \cdot \sin \omega t. \tag{4}$$

Then acceleration will be determined by the following expression (5):

$$\ddot{x} = -\omega^2 \cdot R \cdot \sin \quad \omega t,$$
$$\ddot{y} = \omega^2 \cdot R \cdot \cos \omega t. \tag{5}$$

The absolute speed (V) and acceleration (a) of the end of the spring pin (d) can be determined by the following expressions [5]:

$$V = \sqrt{\dot{x}^2 + \dot{y}^2} = \sqrt{V_{\Pi}^2 + \omega^2 R^2 + 2V_{\Pi}\omega R \cos \omega t},$$
$$a = \sqrt{\ddot{x} + \ddot{y}} = \omega^2 R_{\Pi}. \tag{6}$$

In the process of lifting the grain mass of the swath, parameter (R_{Π}) is of significant importance, which is determined by expression (7):

$$R_{\Pi} = \sqrt{\Delta l^2 + R_{Л}^2 + 2\Delta l R_{Л} \cos \beta}, \tag{7}$$

where $\Delta l -$ length of the spring pin protruding above the pickup conveyor belt, m;

$R_{Л} -$ radius of the pickup conveyor belt, m;

$\beta -$ angle of the pin deflection from its radial location, deg.

The circumferential path of the spring pins is then equal to:

$$S = \frac{2 \cdot \pi \cdot R_{\Pi}}{N}, \tag{8}$$

where $N -$ number of rows of spring pins located on the conveyor belt shaft.

Depending on the value of the dimensionless parameter $\lambda = V_{\Pi} / V$, ($1 < \lambda < 1$), the trajectory of the spring pin will be both an elongated and a shortened cycloid.

When the spring pin is deflected forward in the direction of rotation of the conveyor belt, the cycloid is displaced towards the lagging side, and when it is deflected in the opposite direction, it is slightly ahead of the trace of the normal position of the spring pin.

Ttrajectories of the spring pins located on two adjacent rows can be described using the following expressions (8) and (9):

$$x_1 = V_{\Pi} \cdot t + R_{\Pi} \cdot \sin \omega t,$$
$$y_1 = H_{\Pi} - R_{\Pi} \cdot \cos \omega t. \tag{9}$$

$$x_2 = V_{\Pi} \cdot t + R_{\Pi} \cdot \sin\left(\omega t - \frac{2\pi}{N}\right),$$
$$y_2 = H_{\Pi} - R_{\Pi} \cdot \sin\left(\omega t - \frac{2\pi}{N}\right). \tag{10}$$

The difference ($x_1 - x_2$) is the linear step of the conveyor pickup, which characterizes horizontal distance between the corresponding points on the trajectories of two successively working pins:

$$L = x_2 - x_1 = \frac{2\pi \cdot V_{\Pi}}{N \cdot \omega} = \frac{2\pi \cdot R_{\Pi}\lambda}{N \cdot \omega} = S \cdot \lambda, \tag{11}$$

where $\lambda = V_{\Pi}/\omega \cdot R_{\Pi}$.

The height of the spring pin at the moment when the grain mass swath starts to rise will be equal to:

$$y_0 = \Delta l + R_{\Pi}(1 - \cos \omega\, t_{НАч}), \tag{12}$$

where $\omega t_{НАч} -$ angle of rotation of the radius vector of the end of the spring pin, corresponding to the moment of start of lifting the grain mass swath, deg.

When the rotation angle of radius vector (R_{Π}) of the end of the spring pin is = $\omega t_{ВР}$ 70 - 750 [71, 81], then the pin is injected into the grain mass of the swath.

From equation (12) it follows that the operation quality of the spring pins of the conveyor pickup depends on the length of the section, which is not overlapped by the trajectories of two successively working adjacent pins, that is, there is an area uncaught by the pins, where the plant material is picked up only due to connectivity of the grain mass swath.

In addition, expression (8) indicates that at the moment ($\omega t_{\text{НАЧ}}$), that is, from the beginning of the rise of the swath's grain mass and until the moment ($\omega t_{\text{ВР}}$), a centrifugal force $\boldsymbol{F} = \boldsymbol{a} \cdot \boldsymbol{m}_{\text{ХЛ}}$ acts on the grain mass located on the spring pin during its rotation, which tends to throw the grain material off the spring pin. However, as a result of the grain mass swath climbing onto the conveyor pickup due to the forward speed of the combine ($V_{\text{К}}$), inertial forces are formed that are directed horizontally and contribute to its capture. The balance of these forces determines whether the grain mass swath will either be lifted off the stubble field or unloaded in front of the pickup.

The negative effect of centrifugal force (F) during interaction of the spring pin with the grain mass of the swath can be reduced by changing the ratio of the reaction of two forces: this are the gravity force (G) of the grain mass and the force ($P_{\text{П}}$) acting from the direction of the spring pins. Since, due to their counteraction, the layer of grain mass is compressed. At the same time, for each meeting of a row of spring pins, the layer of grain mass experiences an impulse of force:

$$F_{И} = P_{П} \cdot \Delta t, \tag{13}$$

where $P_{\text{П}} = P_{\text{Н}}(f_{\text{П}} - f_{\text{С}}) -$ resultant, equal to the difference between the friction forces of a row of spring pins against the grain mass and the stalks of the grain mass swath against each other;

$P_{\text{Н}}$ – normal pressure in the compressed layer of the grain mass;

Δt – time of meeting duration, s.

$f_{\text{П}}$ and $f_{\text{С}}$ – coefficients of friction of the pins on the swath's stalks and the stalk on the stalk of the grain mass.

The value of the friction coefficient of the spring pin on the crop mass of the swath ($f_{\text{П}}$) can be improved by changing the geometry of the pickup surface of the spring pin of the conveyor belt of the grain pickup.

In general, the change in the geometry of the working surface of the spring pin is shown in Fig. 2.

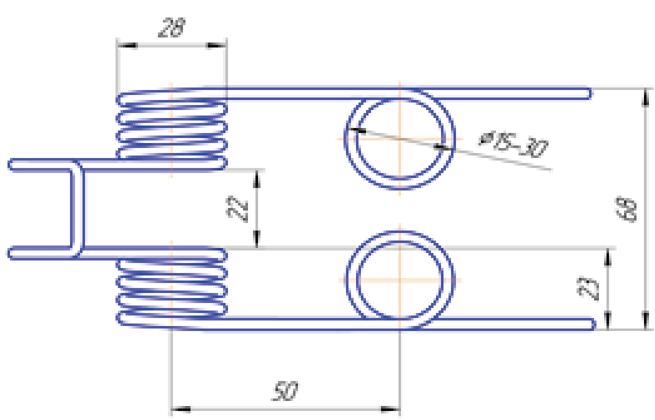

FIGURE 2. General view of changing the geometry of the spring pin (Pat. No.158040 RU IPC A 01 D 89/00) [5,6]

Figure 2 shows that due to formation of an annular coil on the pickup surface of the spring pin, the contact area with the plant material changes, which will help to reduce the negative impact of the centrifugal force of the spring pin on the grain mass of the swath, and, therefore, will affect the grain loss behind the conveyor pickup.

However, it should be borne in mind that the presented pin will be very difficult to manufacture, therefore, changing the geometry of the picking surface of the spring pin of the grain crop pickup can be performed as follows (Fig. 3 and 4):

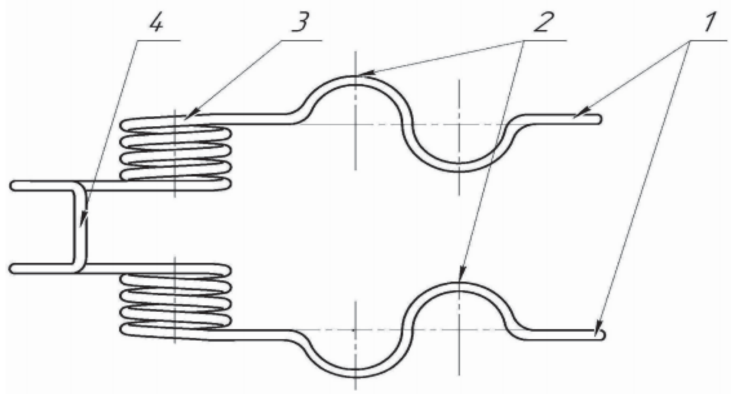

FIGURE 3. Pickup surface made in the form of two semicircles facing different directions
(Pat. No.194973 RU IPC A 01 D 89/00) [7]

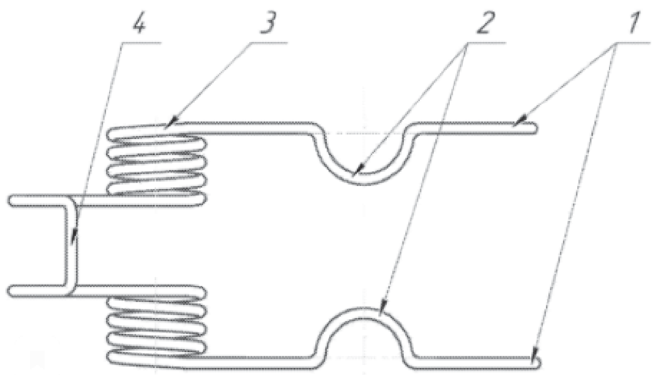

FIGURE 4. Pickup surface made in the form of semicircles
(Pat. No.187917 RU IPC A 01 D 89/00) [8]

CONCLUSIONS

Thus, the results of the analysis of interaction of the spring pin of the pickup conveyor belt with the grain mass of the swath indicate the advisability of reducing the negative impact of the centrifugal force, which tends to throw the crop mass of the swath off the spring pin. In practice, this can be done by increasing the contact area of the spring pin with the grain mass by forming an annular coil on its working length. Therefore, in the future, it is necessary to consider the change in the geometric parameters of the annular turn on the working length of the spring pin of the conveyor belt of the grain crop pickup, and also take into account technological aspects of manufacturing these pins.

REFERENCES

1. Konstantinov M.M., Glushkov I.N. Assessment of the level of grain loss behind a portioned header equipped with a device for the formation of stubble links. Izvestia of the Orenburg State Agrarian University. 2016. No. 3 (59). pp. 86-89.
2. Glushkov I.N. Substantiation of parameters and operation modes of a portioned header with a link formation device: diss. ... Cand. Tech. Sciences. Orenburg, 2013.141 p.
3. Konstantinov M.M., Glushkov I.N., Pashinin S.S. Analysis of the joint work of the reel of the stubble bed formation device and the main reel of the portioning header. Uralskiy promyshlennik. 2015. No. 10. pp. 54–56.
4. Konstantinov M.M., Glushkov I.N., Pashinin S.S. Substantiation of the speed ratio of the storage conveyor and the power unit of the portioning header. Scientific Review. 2015. No. 11. pp. 24–29.

5. Ognev I.I. Reducing grain losses behind a pickup during combine harvesting by improving the pickup surface of spring pins: dis. ... Cand. Tech. Sciences. Chelyabinsk, 2017,143 p.
6. Patent No. 158040 RU IPC A 01 D 89/00. Pickup spring pin for the conveyor pickup of a combine harvester. A.P. Lovchikov, I.I. Ognev. No. 2015118490/13; declared 05/18/2015; publ. 12/20/2015. Bul. No. 35.7.
7. Patent No. 187917 RU IPC A 01 D 89/00. Spring pin of the conveyor pickup of the harvesting machine. I.I. Ognev, I.G. Ognev, S.A. Bannykh (et al.) No. 2019109847: appl. 04/03/2019; publ. 09.01.2020.
8. Patent No. 187917 RU IPC A 01 D 89/00. Spring pin of the conveyor pickup of the harvesting machine. I.I. Ognev., I.G. Ognev., A.P. Lovchikov, D.V. Vlasov No. 2018142301: appl. 30.11.2018: publ. 03/22/2019.