Researches of the combined coulter working process for direct strip sowing of seeds

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Abstract. In this paper We presented design of analytic dependencies of main geometrics parameters of combine coulter distributor for direct strip sowing of cereals with accounting of pass speed of particle from the distributor.

1 Introduction

More perspective direction for conditions of the Russian Federation is development seeder of direct sowing with passive working bodies if we will take in account higher reliability in working, relatively simple construction and accordingly, the lower cost in manufacturing and in purchasing by the agricultural producer. At the same time, combined working bodies for direct sowing of cereals are perspective. They ensure the uniform distribution of seeds over the feeding area. Researches of justification of the main parameters of the combined coulter of the direct sowing seeder are actual tasks especially for ensuring high-quality strip sowing of cereals in compliance with agrotechnical requirements for zero tillage [1-6].

2 Material and methods

In the strip sowing, one part of the seeds enters to the soil through the seed tube 2 in the central part of the coulter, and other seeds scatter across the soil with a distributor in duckfoot sweep 1, which forms the seeding strip Figure. 1.

For this function, It is necessary to find the geometric correlation between the constructions elements of the distributor for a given sowing strip width b_n , the transverse dimensions of the seed tube outlet pipe: length L_c and width b_c , dihedral angle 2γ at the top of the distributor, clearance Δh between the lower edge of the distributor and the soil, subsweep height H_c Figure. 2.

We chose such defined parameters of the distributor: the distributor width (b_p , the length of the rectilinear section of the distributor surface $L_n=AB$, the length of the curved section of

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the distributor surface $L_K=BC$, the radius of the curvilinear area circle of the distributor surface R , the angle of inclination of the edge δ to the longitudinal axis of the coulter, central angle α of the generatrix of the curvilinear area, the height of the distributor top H_p , the distance h_o from the soil surface of the center of the circle of the curvilinear area of the distributor surface (point O) and the distance l_o from distributor axis to the specified center.

It was made mathematical analysis of the association of the geometric distributor parameters in accordance with the calculation scheme. Figure. 2.

Fig. 1. Combined coulter scheme: 1 is duckfoot sweep; 2 is seed tube; 3 is opener stand; 4, 5 are hole for mounting the coulter; 6, 8 are mounts for a circular knife; 7 is stand of a circular knife; 9 is a fork of a stand of a disk knife; 10 is circular knife.

Fig. 2. The calculation scheme for justification of the distributor geometric parameters

3 Results and discussion

Space between the rectilinear area AB and the seed tube can be selected according taking into account the grain particle length, i.e. $M_1M=l_z$, for free passage of a grain particle with length l_z to a curved linear area of the BC surface. Then the horizontal projection MM_2 of the indicated segment from ΔMM_1M_2 is equal to

$$MM_2 = \frac{l_z}{\cos \gamma}. \quad (1)$$

According this, the magnitude of the horizontal projection of the rectilinear generatrix area AM_2 , is determine by equation (2), which located inside the seed tube

$$A_1M_2 = \frac{b_c}{2} - \frac{l_z}{\cos \gamma} = \frac{b_c \cos \gamma - 2l_z}{2 \cos \gamma}, \quad (2)$$

And Its vertical projection – interval AA_1 , is equael:

$$AA_1 = \frac{A_1M_2}{\operatorname{tg} \gamma} = \frac{b_c \cos \gamma - 2l_z}{2 \sin \gamma}. \quad (3)$$

Then distance from the distributor top (point A) to the soil surface is determining by dependence:

$$H_p = H_c + AA_1 = \frac{2H_c \sin \gamma + b_c \cos \gamma - 2l_z}{2 \sin \gamma}. \quad (4)$$

B ΔCD_1D hypotenuse of the SD is coinciding with the particle flight trajectory when its leaving the distributor at the speed V_c . With this in mind, the particle motion time t_z can be determined according to the free-fall law of a moving particle from the height of $SD1 = \Delta h$ in the SD section.

From the physics course it is known that in this case $\Delta h = \frac{gt_z^2}{2}$, from $t_z = \sqrt{\frac{2\Delta h}{g}}$, and

$$CD = V_c t_z = V_c \sqrt{\frac{2\Delta h}{g}}. \quad (5)$$

From the triangle $\Delta DSD1$ it follows that:

$$\Delta h = CD \cos \angle DCD_1 = V_c \cos \angle DCD_1 \sqrt{\frac{2\Delta h}{g}}. \quad (6)$$

But from a comparison of the angles $\angle COK$ and $\angle DCD_1$ it follows that $\angle DCC_1 = \alpha + \gamma$, therefore, taking into account (6)

$$\cos(\alpha + \gamma) = \frac{\Delta h}{V_c \sqrt{\frac{2\Delta h}{g}}} = \frac{\sqrt{2g\Delta h}}{2V_c}, \quad (7)$$

and

$$\sin(\alpha + \gamma) = \sqrt{1 - \frac{g\Delta h}{2V_c^2}} = \sqrt{\frac{2V_c^2 - g\Delta h}{2V_c^2}}. \quad (8)$$

From ΔDCD_1 we are finding

$$D_1 D = CD \sin(\alpha + \gamma) = V_c \sqrt{\frac{2\Delta h}{g}} \sqrt{\frac{2V_c^2 - g\Delta h}{2V_c^2}} = \sqrt{\frac{(2V_c^2 - g\Delta h)\Delta h}{g}}. \quad (9)$$

Then parameter b_p is determining from rule $\frac{b_n - b_p}{2} = D_1 D$

where

$$b_p = b_n - 2 \sqrt{\frac{(2V_c^2 - g\Delta h)\Delta h}{g}}. \quad (10)$$

Taking into account ΔOBK_1 and ΔOCK , it follows from the geometric scheme that

$$H_p - AB_1 - \Delta h = KC - BK_1, \quad (11)$$

but

$$AB_1 = \frac{l_n}{tg\gamma}, \quad (12)$$

where $l_n = BB_1$ – horizontal projection of the generatrix of the rectilinear section AB.

From ΔOBK_1 and ΔOCK , on the one hand, it follows that

$$KC - BK_1 = R \sin(\alpha + \gamma) - R \sin \gamma. \quad (13)$$

С учетом (12) и (13) выражение (11) принимает вид

$$H_p - \frac{l_n}{tg\gamma} - \Delta h = R \sin(\alpha + \gamma) - R \sin \gamma. \quad (14)$$

In view of (12) and (13), expression (11) takes the form

$$KK_1 = D_1 D_3 = R \cos \gamma - R \cos(\alpha + \gamma), \quad (15)$$

and

$$D_1 D_3 = O_1 D - B_1 B - D_1 D \quad (16)$$

In view of (6) and (16), expression (15) takes the form

$$\frac{e_{II}}{2} - \sqrt{\frac{\Delta h(2V_c^2 - g\Delta h)}{g}} - l_{II} = R \cos \gamma - R \cos(\alpha + \gamma). \quad (17)$$

Thus, we obtain the system of equations (14) and (17)

$$\left. \begin{aligned} H_p - \frac{l_n}{tg\gamma} - \Delta h &= R \sin(\alpha + \gamma) - R \sin \gamma \\ \frac{b_n}{2} - \sqrt{\frac{\Delta h(2V_c^2 - g\Delta h)}{g}} - l_n &= R \cos \gamma - R \cos(\alpha + \gamma) \end{aligned} \right\}. \quad (18)$$

From the first equation of the system we express l_n :

$$l_n = (H_p - \Delta h)tg\gamma - Rtg\gamma[\sin(\alpha + \gamma) - \sin \gamma]. \quad (19)$$

Substituting (19) into the second equation of system (18), we have

$$b_n - 2\sqrt{\frac{\Delta h(2V_c^2 - g\Delta h)}{g}} - 2(H_p - \Delta h)tg\alpha = 2R(\cos \gamma - \cos(\alpha + \gamma)) + tg\gamma[\sin(\alpha + \gamma) - \sin \gamma]. \quad (20)$$

From where it follows that

$$R = \frac{b_n - 2\sqrt{\frac{\Delta h(2V_c^2 - g\Delta h)}{g}} - 2(H_p - \Delta h)tg\gamma}{2\{\cos \gamma - \cos(\alpha + \gamma) + tg\gamma[\sin(\alpha + \gamma) - \sin \gamma]\}}. \quad (21)$$

From $\triangle ABB_1$, the length of the rectilinear section $L_n = AB$, taking into account (19) and (21), is expressed as follows

$$L_n = \frac{l_n}{\sin \gamma} = \frac{H_p - \Delta h}{\cos \gamma} - \frac{\left[b_n - 2\sqrt{\frac{\Delta h(2V_c^2 - g\Delta h)}{g}} - 2(H_p - \Delta h)tg\gamma \right] [\sin(\alpha + \gamma) - \sin \gamma]}{2[\cos \gamma - \cos(\alpha + \gamma)] \cos \gamma + \sin \gamma [\sin(\alpha + \gamma) - \sin \gamma]}. \quad (22)$$

It follows from (7) that

$$\alpha = \arccos \frac{\sqrt{2g\Delta h}}{2V_c} - \gamma. \quad (23)$$

Then the length of the generatrix of the distributor curved area $L_k = BC$ is determining by the expression

$$L_k = R\alpha = \frac{\left[b_n - 2\sqrt{\frac{\Delta h(2V_c^2 - g\Delta h)}{g}} - 2(H_p - \Delta h)tg\gamma \right] \left(\arccos \frac{\sqrt{2g\Delta h}}{2V_c} - \gamma \right)}{2\{\cos \gamma - \cos(\alpha + \gamma) + tg\gamma[\sin(\alpha + \gamma) - \sin \gamma]\}}. \quad (24)$$

In view of (8) and (23), the parameter h_o is expressed by the following dependence

$$h_o = R \sin(\alpha + \gamma) + \Delta h = \frac{\left[b_n - 2\sqrt{\frac{\Delta h(2V_c^2 - g\Delta h)}{g}} - 2(H_p - \Delta h)tg\gamma \right] \sqrt{\frac{2V_c^2 - g\Delta h}{2V_c^2}}}{2\{\cos \gamma - \cos(\alpha + \gamma) + tg\gamma[\sin(\alpha + \gamma) - \sin \gamma]\}} + \Delta h, \quad (25)$$

and the distance from the distributor axis to the center of curvature of the BC area (point O) is determined as follows with using dependencies (19) and (21),

$$l_o = (H_p - \Delta h)tg\gamma - Rtg\gamma[\sin(\alpha + \gamma) - \sin\gamma] + R\cos\gamma =$$

$$= (H_p - \Delta h)tg\gamma - \frac{\left[b_n - 2\sqrt{\frac{\Delta h(2V_c^2 - g\Delta h)}{g}} - 2(H_p - \Delta h)tg\gamma \right] [\cos\gamma - tg\gamma(\sin(\alpha + \gamma) - \sin\gamma)]}{2[\cos\gamma - \cos(\alpha + \gamma) + tg\gamma(\sin(\alpha + \gamma) - \sin\gamma)]}. \quad (26)$$

From $\Delta MD2C$ we are determining

$$\delta = \arctg \frac{b_p - b_c}{2l_p} = \arctg \frac{b_n - 2\sqrt{\frac{(2V_c^2 - g\Delta h)\Delta h}{g}} - b_c}{2l_p}. \quad (27)$$

Conclusion

The obtained analytical dependences (4), (7), (10), (19), (21) - (27) are reflected the correlation of the main distributor geometric parameters of the combined coulter for direct strip sowing of cereals with taking into account the particle pass speed from the distributor.

The showing dependencies can be used in the manufacture of test samples of the distributor and the development of methods for its engineering calculation.

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