

Disc Seeder with the System for Automative Tracking Of Sowing Depth

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Abstract— Observance of the depth of sowing of grain crops within the limits established by agro technical requirements is a guarantee of high yield. When the disc coulter moves in the soil, a variable resistance force acts on it, which affects the seeding depth and the qualitative characteristics of the shoots. Since within the same field there are different soils, the depth of sowing with the serial coulters becomes not stable. To solve this problem, the article proposes a technical solution and an automated tracking system that, in combination, ensures the uniformity of seeding depth with disc coulters. The use of a flexible tubular element in the opener coulter design makes it possible to compensate for movements from the soil resistance force in real time. In this paper, a mathematical analysis of the dependence of the influence of the seed depth on the compensating force on a flexible tubular element is made, and the maximum values of this force are determined.

Keywords— *seeder, seeding depth, automation, soil resistance.*

I. INTRODUCTION

Presowing soil cultivation and sowing of agricultural crops are the most energy intensive and fundamental for obtaining high yields. The main indicators that affect the economic component of the entire agricultural process are the traction resistance and the depth of the working bodies. Even in the middle of the twentieth century, scientists asked about the uniformity of the depth of soil cultivation and sowing, as well as its provision under the condition of minimal traction resistance [1]. At present, this problem is actively investigated, revealing the relationships between the depth of soil cultivation, sowing and the yield of different crops [2], justifying the economically expedient depth of tillage without reducing the yield [3]. The main problem in sowing is the strength of soil resistance, which constantly changes depending on the physical and mechanical properties of the soil. Acting on the opener, it contributes to the uneven depth

of movement and, consequently, the uneven depth of seeding, especially when using No-Till technology [4].

In the serial construction of the seed drill, a compression spring is installed to set the coulter penetration force, which is adjusted by the operator before starting work. But it has a constant stiffness and is not capable of changing the clamping force during the movement of the unit. To provide the necessary depth of crop planting, various control systems and automatic control of coulter movement are currently used [5,6]. Hydraulic cylinders are used as the actuating element, which facilitates the displacement of the coulter in the vertical plane. To determine the depth of the working body, methods such as preliminary mapping of the fields [7], tilt sensors of the coulter leash [8], as well as ultrasonic tracking sensors [9] are used.

We propose to use flexible tubular elements [10] in the design of the disc coulter suspension to ensure the set seeding depth. These elements have already been used in work in the modes of power loads [11] and in soil processing [12], which confirms their efficiency.

II. THEORETICAL BACKGROUND

The object of research is the process of interaction of the disc coulter with soil, which has various physical and mechanical properties. The research used methods and elements of higher mathematics, the basic laws of physics and the mechanics of solids.

The sowing unit, consisting of a tractor and a seeder, is a fairly complex dynamic system with significant degrees of freedom. In addition, the seeder is a constant change in the volume of seeds in the hopper and the speed of movement. To be able to create a calculation scheme, we present a sowing unit in the form of any operator – W_{c1} (fig. 1). The profile of the field surface can be distinguished as input parameters of the impact on the seeder $z_n(t)$ and the resistance force of the soil $R(t)$.

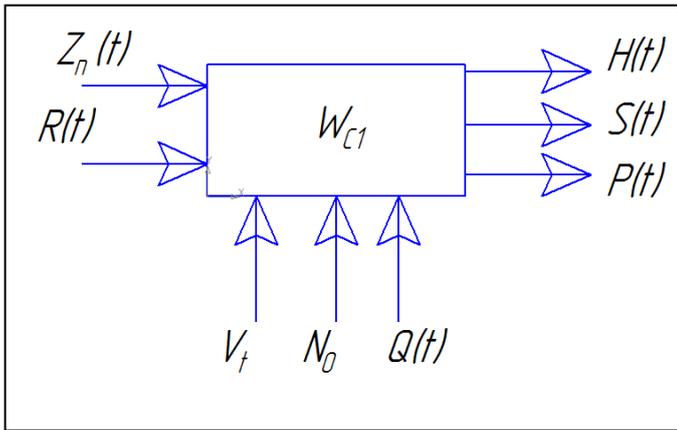


Fig. 1. Dynamic block diagram of sowing unit

Output parameters of the quality of work of the sowing unit it is possible to allocate the following variables:

- H(t) - the uniformity of distribution of seeds with depth;
- S(t) – uniformity of seed distribution by area;
- P(t) – traction resistance of the seeder.

The output parameters are also influenced by the speed of movement of the unit V_f , the initial settings of the seeder N_0 and the change in the seed in the box $Q(t)$. It should be noted that when the unit moves across the field, there are fluctuations in the tractor and the seeder, which also affect the quality indicators of the sowing process. We include them in the external perturbation $z_n(t)$.

For the analysis of the technological process of the planting design scheme needs to consider the change of state of a flow of seed when moving from silo to soil (fig. 2 a).

In this scheme, the change in the field profile and the structure of the soil affect the seed drill frame through propellers 1. The result of these influences are fluctuations $\Delta(t)$. Sowing machines 2 with initial setting N_0 $\Delta(t)$ under the influence of fluctuations $k_1(t)$ which, passing through the seminal duct 3, is transformed into $k_2(t)$. Opener 4, installed at the required depth H_0 converts the flow of seeds into $k_3(t)$, which enters the furrows formed by the coulters. Interaction of the opener 4 with soil 5 leads to a random distribution of seeds to the depth of the seal $h(t)$. Seed depth h_s this is a random process of changing the distance between the field surface and seeds.

The change in the surface profile of the field $z_n(t)$ is an external factor affecting the uniformity of the depth of the opener stroke. In connection with this, the distribution of the depth at which the seeds are embedded is also not constant – $z_c(t)$. The change in the physic-mechanical properties of the soil, which affect the depth of the coulters stroke, is hidden in the characteristic of the soil resistance force acting on the coulters. In this regard, it is necessary to analyze the effect of this force on the disc coulters.

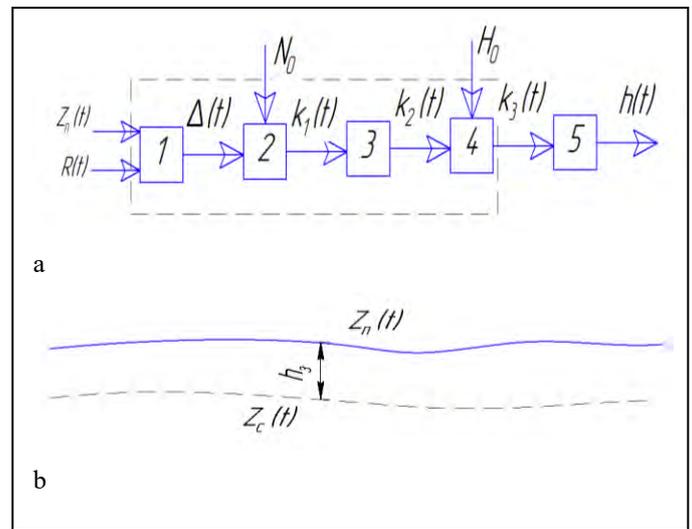


Fig. 2. Process of movement opener: a – Block diagram of the seeder; b – depth of seeding

To maintain the established depth of the disc coulters with the proposed suspension on different types of soils, it is necessary to establish the relationship between the soil resistance force and the force created by the flexible tubular element under the action of pressure (Fig. 3). If we consider the coulters-soil system in the first approximation, we can distinguish the following forces: the soil resistance R , the gravity of the opener with the leash G , the strength of the elastic element F . Before starting the work, the disk is set to a depth h due to the forces of gravity and the elastic element. When the unit moves with a speed VT , a resistance force acts on the soil side, which tries to move the coulters in the direction "A", reducing the depth of sowing. To return the coulters to the set depth h , the fluid in the tubular element is supplied under pressure, deforming its cross section, thereby creating a force F that moves the disk in the direction opposite to "A".

In order for the depth of the coulters to be constant it is necessary that the following condition be satisfied:

$$\sum M_0 = 0 \tag{1}$$

We substitute the moments of forces acting on the coulters into the left side of equation 1:

$$R \cdot l_3 - G \cdot l_2 - P \cdot l_1 = 0 \tag{2}$$

where: R - the value of the soil resistance force, H ;
 G - force of gravity, N ;
 F - the force created by the flexible tubular element, H ;
 l_1, l_2, l_3 - the values of the arms of the above forces, mm.

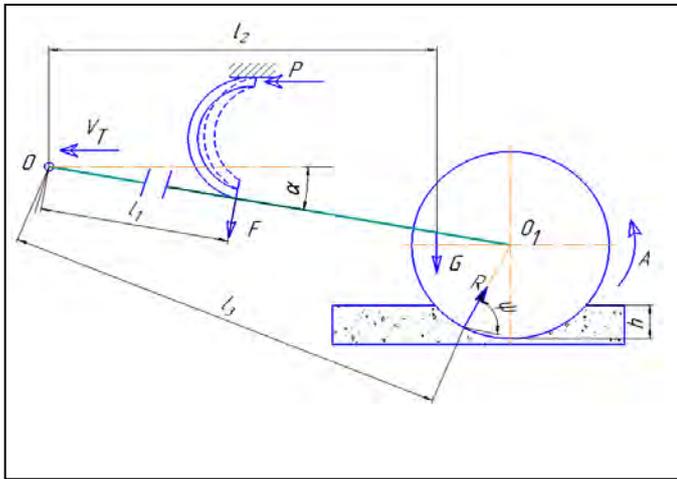


Fig. 3. Calculation scheme of the opener balance

The action line of the resultant soil resistance R passes through the center of the opener disc O_1 and is located at an angle ψ with respect to the horizon. When the seeding depth is changed, the angle ψ also changes, so the value of the arm l_3 is more conveniently expressed in terms of the length of the opener of the opener OO_1 , taking into account the inclination angle of the lead to the horizon- α :

$$R \cdot \cos \psi \cdot OO_1 \cdot \sin \alpha + R \cdot \sin \psi \cdot OO_1 \cdot \cos \alpha - G \cdot l_2 \cdot \cos \alpha - F \cdot l_1 \cdot \cos \alpha = 0. \quad (3)$$

The value of the soil resistance R has a dependence on the speed of movement of the aggregate, the depth of the vomer and the physico-mechanical properties of the soil, which vary with time. Therefore, this effort can be represented as a function:

$$R = f(t) \quad (4)$$

On the basis of this, the force created by the flexible tubular element must have a variable value compensating for the action of the force (4)

$$F(t) = (R \cdot \cos \psi \cdot OO_1 \cdot \sin \alpha + R \cdot \sin \psi \cdot OO_1 \cdot \cos \alpha - G \cdot l_2 \cdot \cos \alpha) / l_1 \cdot \cos \alpha. \quad (5)$$

In real time, it is difficult to keep track of the parameters to be changed; therefore, in order not to become attached to the physico-mechanical characteristics of the soil, we propose to select the distance from the seeder frame to the axis of rotation of the opener disc-point O_1 (Fig. 4) for the input parameter. Under the action of the resistance force, the opener disc rotates relative to the hinge of the leash - point O , deepening. To fix the movement data, an optical distance sensor 1 is mounted on the seeder frame. At rest, this distance is considered nominal. Under the influence of resistance, moving the disk in a vertical direction within the agrotechnical requirements, changes the measured distance in the range $\pm \Delta$. The signals from the sensor 1 are transmitted to the control unit 2.

In the hydraulic system of the tractor, consisting of a tank 5, a gear pump 4, a hydraulic distributor 3 with electromagnetic control is installed. The cavity of the flexible

tubular element 7 through the union is connected by hoses 6 to the hydraulic distributor.

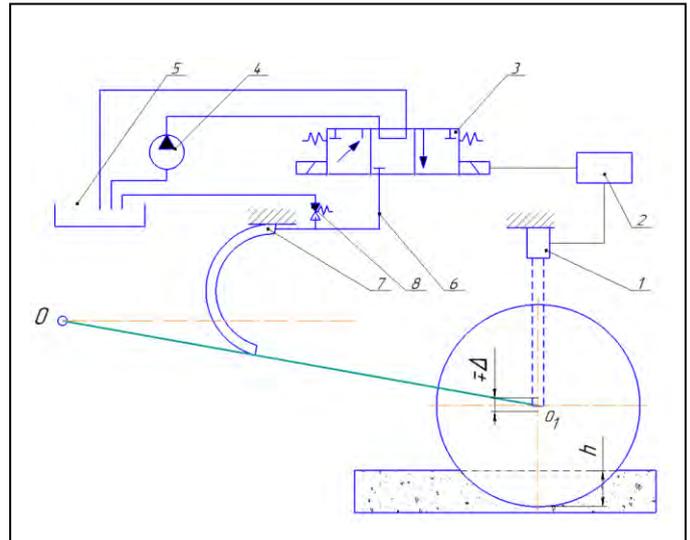


Fig. 4. Schematic diagram of the depth control system

In the process of planting crops with increasing resistance force, sensor 1 fixes the movement of point O_1 beyond the specified range $\pm \Delta$. This signal is transmitted to the control unit, which moves the hydraulic distributor into the position of fluid entering the cavity of the flexible tubular element. As the pressure increases, the cross-section of the element begins to deform, tending to the circumference, deepening the disc of the opener to the set depth. In this case, the distance fixed by the sensor to $m. O_1$ increases until the moment it hits the specified range $\pm \Delta$. At this point, the control unit receives a signal and the hydraulic distributor is reset to its original position and the cavity of the element becomes sealed while maintaining the created hydraulic pressure.

When the strength of the soil resistance decreases due to the deformation of the flexible tubular disk, the disk becomes deeper and the sensor fixes the increase in the distance to the point O_1 . In case this distance exceeds the permissible range, a signal is sent to the control unit and the hydraulic distributor is transferred to the mode of bleeding liquid from the element cavity to the tank. This mode is active until the distance measured by the sensor does not satisfy the original parameters.

If the pressure created is not sufficient to return the disc to the set depth and the control unit does not limit the fluid pressure, a safety valve 8 is provided in the oil line. This valve is adjusted to the maximum possible pressure within the strength of the material of the flexible tubular element before operating the unit.

To determine the strength of the force of the elastic element, which is necessary to stabilize the depth of the coulter stroke, we will use the technique of calculating the direction and value of the soil resistance force acting on the

disc coulters [13]. Using the calculation scheme (Fig. 1) and expression (6), we determine the value of the force F from the depth of the coulters motion. For calculations, take the parameters of the serial opener seeder SZ-3,6 with a long lead: $OO_1 = 850\text{mm}$; $l_1 = 350\text{ mm}$; $l_2 = 700\text{ mm}$; $D = 350\text{ mm}$ - diameter of the disc of the opener; $G = 100\text{N}$ - coulters weight; $b = 80\text{mm}$ - the width of the opener, $\alpha = 30^\circ$ - the angle of inclination of the opener to the horizon; $k = 0.05 \dots 0.20\text{ MPa}$ is the specific resistance of the soil during sowing. Let's choose a range of depth of coulters movement equal to $20 \dots 100\text{ mm}$. Using the computer algebra system MathCAD, we present the results as a graph in Fig. 5.

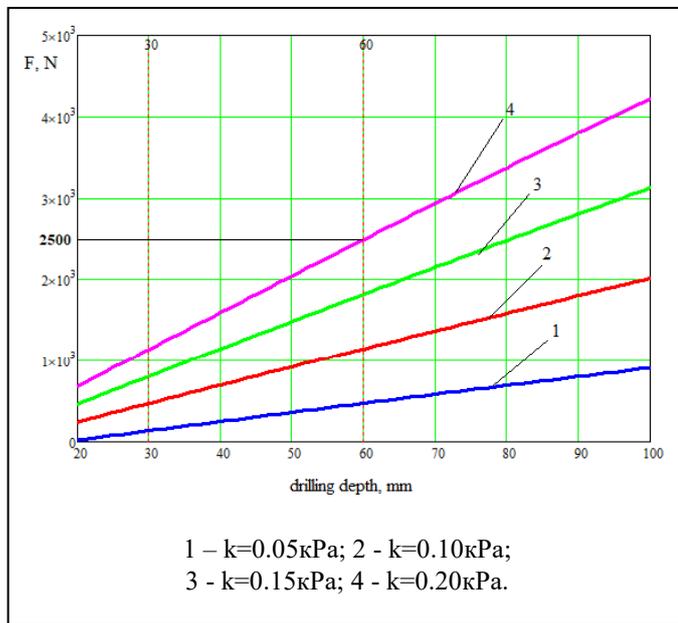


Fig. 5. - Dependence of the elastic element force on the depth of seeding

The obtained dependences characterize the stress-strain state of a flexible tubular element used in the adaptive suspension of a disc coulters.

III. CONCLUSION

The application of the proposed automated tracking system will allow to stabilize the depth of seeding with disc coulters. The deviation of the seed depth from the preset will result in a change in the hydraulic pressure in the flexible tubular element and move the coulters to its original depth. On heavy soils with a resistivity of $k = 0.20\text{ kPa}$, when sowing to a depth of $30..60\text{ mm}$, it is sufficient that the force at the end of the flexible tubular element is $750 \dots 2500\text{ N}$. The uniformity of movement in light soils is provided by a lower pressure in the cavity of the flexible tubular element.

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