Energy-Saving Method of Basic Tillage and Soil and Design for Its Implementation

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Abstract. The article is devoted to the analysis of mechanization tools for mineral fertilizer application systems of enterprises of various forms of ownership, which can be used for implementation into the production process. This will allow us to further develop a machine design that would be able to fully meet the initial agrotechnical requirements for working in conditions of limited land use. We conducted a patent search using publicly available tools.

1 Introduction

For sowing seeds of grain crops, from the point of view of providing an area of nutrition and convenience of caring for plants, it is advantageous to use an ordinary method of sowing [1-3]. At the same time, one of the qualitative parameters of sowing is the distribution of seeds along the length of the row [1-5], contributing to ensuring equal conditions for the area of nutrition of each plant. Its influence is especially pronounced taking into account the need to sow a wide range of crops at different seeding rates [6]. This parameter is influenced by the design parameters and operating modes of the seeding device. The most common among all other seeding units are coil ones, the main advantages of which are simplicity of design and reliability. However, the parameters and operating modes of such devices, which ensure a uniform distribution of seeds along the length of the furrow, have not been sufficiently studied. As a rule, in such devices, grooved seeding coils are used, having both a straight and a screw shape, the working volume of which is regulated by a flap, and not by adapting the shape of the coil to the seeding conditions, which does not improve the uniformity of seeding to the proper extent. In addition, at present, conditions are being created for the increasing availability of the use of composite materials and 3D printers as means capable of producing a wide range of geometric shapes of the product using materials that ensure operation in various conditions and for sowing a wide variety of crops.

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It is also worth noting that the gearboxes of seeders for the drive of coil devices are in most cases quite metal-intensive and their use contributes to an increase in labor intensity, with frequent changes in the seeding rate or crops being sown, especially in conditions of breeding plots [7]. Among the devices on the market, it is worth highlighting seeding devices with a stepper motor [8], the principle of operation of which is based on pulsed alternating voltage supply to the motor windings, which creates a reactive rotational force. And unlike collector motors, stepper motors are capable, without losing torque at low speeds, of turning at a given angle depending on the number of pulses applied to the windings. The pitch of such motors is measured in degrees by which the rotor rotates. This advantage significantly complicates the design and is not always economically justified. In addition, the phenomenon of resonance is inherent in a stepper motor [9]. The use of collector electric motors in seeders with an electronic control system has found application in APV sowing units [10], which on the one hand made it possible to get rid of the chain drive and gearbox used in classic grain seeders, on the other hand, the use of this type of electric motor does not entail a significant complication and increase in the cost of the design with comparable reliability. The digital control module, which helps to regulate the operating modes of the APV seeding unit, reduces the labor intensity when changing the sown crops and seeding rates with the required accuracy, which is provided by the stepless rotation mode of the seeding shaft.

Thus, the study of the geometric parameters of the actuators for seeding – coils and the modes of operation of the seeding unit using electric seeders and an electronic control system, where the dependences of the uniformity of the distribution of seeds along the furrow length on the design parameters of the elements of the seeding unit of the seeder and the sowing modes of winter wheat seeds are considered as the subject of research. The aim of the work is to improve the uniformity of the distribution of the area of nutrition that falls on each plant with an ordinary method of sowing winter wheat.

2 Materials and methods

The mechanical effect of the plow on the soil is accompanied by resistance, the magnitude of which depends on many factors. Many researchers, having determined the relationship between the physical and mechanical properties of the soil and its qualitative indicators of processing, give various forms of calculations using various formulas. They are aimed at determining the traction resistance when plowing with various tillage tools. Also, leading scientists identify several factors that affect the quality of plowing and the energy process of tillage itself:

- physical and mechanical (hardness, stickiness, humidity, borehole, etc.)
- technical (type of construction of the tillage unit, its condition, adjustment, etc.)
- technological (processing method, plowing depth, processing speed, etc.)

It is also generally accepted that the traction resistance of a tillage unit consists of useful and harmful resistances of its working organs. The value of useful resistances depends on the size and geometric shapes of the ploughshares and plowshares used, the depth of processing, as well as on the friction properties of the materials used in the manufacture of working bodies. Harmful resistances depend on the magnitude of the friction force of the field boards against the vertical wall of the furrow, on the degree of wear of the blades of the working bodies, on the load on the support wheels of the mover and the trolley of the working bodies, as well as their rolling resistance.

In the works of many scientists, dependencies have been identified and patterns of the influence of hotel factors on the energy intensity of the tillage process with various tools have been revealed. Taking into account these circumstances, it is possible to compile and present a classification of ways to reduce energy consumption for tillage.

The following are accepted as the main methods of reducing energy costs for plowing:

- reduction of soil deformation efforts;
- reduction of friction forces;
- optimization of parameters of working bodies and operating modes of machine-tractor tillage units;
- improvement of the designs of tillage machines;
- the use of combined machines and tools;
- the transition to energy-saving technologies.

The relationship of all these indicators is shown in Fig. 1. This scheme most fully shows the picture of the relationship between the influence of certain factors on the energy intensity of the plowing process. However, when analyzing the scheme, it can be judged that at the moment none of the likely directions has been widely used in industry except for the use of feather dumps.

This is due to the fact that in many cases the design of the plow becomes more complicated, the installation of complex additional working bodies is required, for the operation of which a higher degree of qualification of the machine operator is required, this in turn leads to an increase in metal consumption and the dimensions of the tool.

The research results show that the least metal-intensive is the ploughshare, which contains three working housings. A further increase in the number of housings leads to an increase in the specific metal content by 12-14%.

Reducing the specific metal consumption, and at the same time reducing fuel consumption, is achieved through the use of more durable or lightweight materials, further improving the design of individual working bodies of the ploughshare [11-17].

In the global trend at the moment, there is a tendency to increase the grip width of the ploughshare housings or variations in the width of their grip directly on the frame of the ploughshare. The classical plow scheme has an irrational principle that affects the energy intensity of the tillage process with the formation turnover. The significant energy consumption for moving the soil layer indicates a significant flaw in the design of the ploughshare housings.

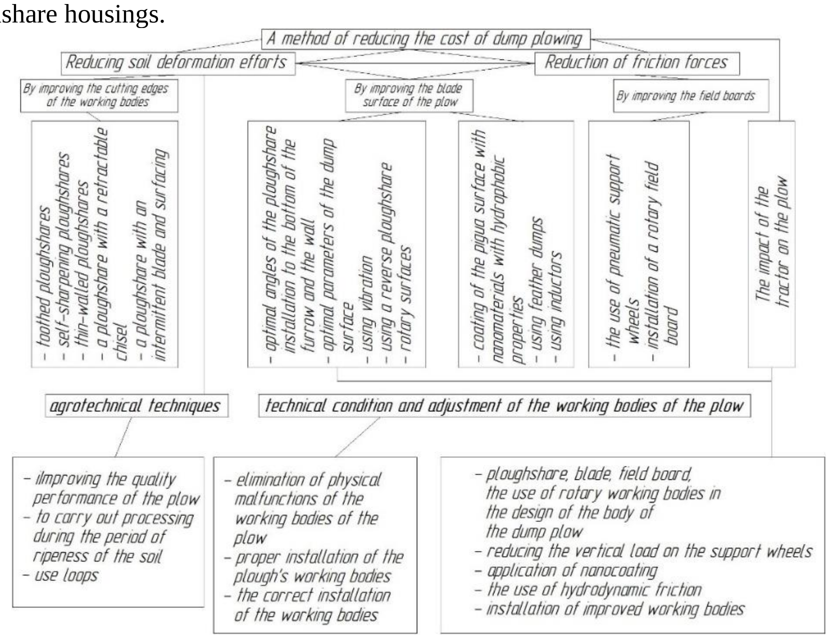

Figure 1. A block diagram of possible methods for reducing energy costs for plowing

Figure 2. The developed additional working body

The technical result of the proposed design is a plane-cutting working body with an additional angle of attack (fig.2), with reasonable areas of placement over the entire area of the slots, ensuring a decrease in traction resistance and quality of tillage - completeness of soil pruning and improvement of quality performance over the entire width of tillage until complete wear of the plane-cutting working body.

3 Results

The above technical result is achieved by the fact that the slots of the plane-cutting working body are located in the area of the working body, taking into account the wear of the part during its operation, and the maximum permissible total area of the slots, at which the required structural strength is maintained, higher stability of the arable unit is ensured. With this technical solution, the quantitative and qualitative indicators of processing of over-dried soils are improved, and when processing wet or waterlogged soils, processing occurs without sticking and, as a result, the traction resistance of the arable unit is reduced.

In more detail, the essence of the design can be explained as follows: when cultivating soil with tillage working bodies, boundary surfaces arise between the soil and the surface of the working bodies, and more specifically, between the soil and steel, namely between adjacent soil bodies - between a thin layer of soil adhering to the working body and a layer of soil, the surface of the working body. In general, with such relative displacements, stresses arise acting across the interface of two bodies - the soil layer on the material of the plane-cutting working body, i.e. about the steel and the soil layer about the soil stuck to the surface of the working body. The normal component of this stress causes sliding friction forces, the tangential component of which is the shear stress caused by friction [1-5].

According to the conclusion of A.Kulen and H. Kuipers, the dependence of soil and material characteristics on the conditions of soil adhesion on the disk can be expressed by the expression of the normal component 〖σ〗_n total voltage P.

$$\sigma_n < \frac{a-c}{tg\varphi - \mu'}, \qquad (1)$$

where a – adhesion;

c – cohesion;

φ – the angle of internal friction;

– the coefficient of friction of the soil on the material of the plane-cutting working body (steel).

Therefore, the growth of the soil without sticking will contribute to the promotion of σп. Therefore, in this regard, it is advisable to use a plane-cutting working body with slots that increase σп, because , where S – the total area of contact of the soil with the surface of the working body of the disc, Pn – the normal component of the total voltage P.

The friction of the soil as it slides over the work surface and sticking are different phenomena, but they manifest themselves simultaneously. Note at the same time that if the sliding friction resistance does not depend on the area of their fit to each other, i.e. F= *f*N, the slip resistance from sticking depends on the area of their contact S. The total slip resistance T caused by them is characterized by the following equation.

$$T = F + T_{np} = fN + p_0 S + pNS, \tag{2}$$

where F – resistance to sliding of the soil on steel (on the surface of the plane-cutting working body);

T_{np} – slip resistance from sticking;

p_o – coefficient of tangential forces of specific adhesion in the absence of normal pressure;

f – coefficient of sliding friction;

S – the area of contact of the soil with the surface is the surface of the plane-cutting working body;

p – coefficient of tangential forces of specific adhesion caused by normal pressure.

4 Conclusion

Analysis of expression (2) also shows that the total resistance T can be reduced by reducing the area of possible adhesion. Therefore, from the point of view of reducing traction resistance, it is necessary to increase the area of the slots of the surface of the plane-cutting working body, and at the same time, the limit of increasing the area of the cutout can only be maintaining the required strength of the surface of the working body. The location of the slots of the plane-cutting working body with the recommended geometric parameters will ensure a decrease in the traction resistance of the arable unit, increase its permeability during tillage, reduce traction resistance, ensure stable movement of the soil layer and cutting weeds across the entire width of the treatment, that is, ensure the achievement of a technical result.

The analysis of the work done indicates that the development of additional working bodies to improve the process of basic tillage makes it possible to improve the qualitative and quantitative indicators of this technological operation. These qualities of tillage were confirmed during field experiments, and the main structural elements were patented. The use of additional organs of the claimed design allows for basic tillage with lower fuel costs and, as a result, to achieve better quality indicators for the cultivation of agricultural products.

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