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CONSTRUCTION AND THEORETICAL JUSTIFICATION OF THE DRILLING RESISTANCE OF THE CUTTER FOR PRODUCTION OF ECOLOGICAL PRODUCTS OF SMALL SEED CROPS

Vladimir OVTOV, Vasiliy SHUMAEV, Andrey KALABUSHEV, Ivan SEMOV

Penza State Agrarian University, 30 Botanicheskaya Street, 440014, Penza, Russia

Corresponding author email: Ovtovvlad@mail.ru

Abstract

Modern technologies for the cultivation of small-seed crops impose increased requirements on the sowing operation, the quality of which is largely determined by the design of the coulters used. The developed design of the coulter for sowing small-seed crops, which qualitatively prepares the planting furrow by leveling and compacting the surface of the bottom of the furrow. The stable distribution of small-seeded crops during their sowing significantly affects their productivity, since this forms the feeding area. Compliance with agricultural requirements for the uniform distribution of seed material is a priority task in the design of coulters and closing bodies of seeders. The use of skid coulters makes it possible to use their single-row installation, which, together with protection against damage when leveling and compacting the bottom of the planting furrow in one structural unit, makes it possible to reduce the metal content of the coulter and increase its compactness. When determining the parameters of the coulter, taking into account the condition of stability of its movement when sowing small-seed crops, a theoretical substantiation of its traction resistance was carried out.

Key words*: soil, small-seeded crops, construction, coulter, resistance, speed.*

INTRODUCTION

Commercial production of small-seed oilseeds, such as oilseed flax, mustard, safflower, rapeseed, camelina, is of increasing interest to domestic producers, and compliance with innovative cultivation technologies makes it possible to obtain fairly high yields. The economic component of growing these crops is due to their demand both in the domestic and world markets. First of all, the product of processing these oil crops is oil, which is widely used in the food industry, cosmetology, and the pharmaceutical industry. In connection with the planned trends for green energy, the production of biodiesel and aviation fuel is becoming increasingly important. In addition, rapeseed and camelina processing products, Among the small-seeded crops grown for fodder, the leading place belongs to alfalfa. Alfalfa is one of the most common crops grown for hay, as it has a high productivity, which makes it possible to obtain two cuts in central Russia. In addition, alfalfa is a high-protein component in the diet of cattle, which contributes to its productivity. Due to the development of a powerful root system, penetrating to a depth of 12 m, alfalfa enriches the soil with nitrogen and organic matter, increases soil fertility, which helps to increase the yield of subsequent crops grown. For example, after a three-year growing cycle, alfalfa is able to leave the same amount of organic matter per hectare asin 60...70 tons of manure (Chapaev, 2006). After harvesting with root and crop residues, an average of up to 200 kg of nitrogen per hectare enters the soil, which in turn reduces the application of mineral fertilizers. In addition, alfalfa helps to improve the physical and mechanical properties of the soil, namely, its bulk density decreases, porosity increases and moisture capacity in the arable horizon increases.

However, the cultivation of small-seeded crops requires compliance with the agrotechnical requirements for the quality of their sowing by existing seeders, which do not provide it completely due to their small seed sizes and certain seeding rates. It is known that in modern sowing units, the technological process of sowing seeds is carried out in the following stages: spilling seeds from the hopper through the hole; dosing of seeds by the sowing device; distribution of the received dose in a row; transportation of seeds from the sowing device to the coulter; furrow formation and incorporation of seeds with soil. Differences in the working processes of sowing units are due to the requirements for the quality of sowing small-seed crops. The quality of seeding

implies, first of all, uniform distribution of seeds over the sown area while ensuring a given seeding rate. All studies, therefore, are characterized by recommendations on the choice of certain elements of the sowing system and closing bodies.
Analyzing the technological process of sowing existing sowing machines of domestic and foreign production, it should be noted that the quality indicators of sowing are to a certain extent dependent on the structural and technological elements of the seeder. These elements include loading and feeding devices, sowing devices, distributing and transporting devices (seed ducts) and closing devices (coulters, compactors).
The uniformity of distribution of seeds in a row, their placement to the required depth and, finally, ensuring the seeding rate depend on how reliably and accurately the technological operation is performed by each element of the machine.
In the technological process of cultivation of small-seeded crops, an important role in sowing is played by the placement of seeds with coulters at a given depth, since the depth of placement of seeds is small from 1 to 3 cm, the deviation from these values leads to a decrease in the quality of seed germination.
Obtaining high yields requires the use of energy-saving technologies that make it possible to achieve optimal distribution of cultivated small-seed crops over the nutritional area in terms of uniformity. As a result of the uneven distribution of plants over the sown area, their field germination and productivity are reduced. The coulter group of the sowing unit is one of the factors that has a significant impact on the quality of placement in terms of depth and width of placement of seeds of small-seeded crops.
The currently used technologies for the cultivation of small-seed crops impose increased requirements on sowing, the quality of which largely depends on the design of coulters designed to form furrows in the soil and uniform distribution of seeds in the furrow (Petrov et al., 2018; Ovtov et al., 2020; Shumaev et al., 2021; Dorohov et al., 2019; Cheremisinov et al., 2016; Ovtov et al., 2021). In most currently produced seeders, the coulters used only form a sowing furrow for laying seeds, and to ensure contact of the seed after covering with a layer of soil by closing bodies with the lower wetter soil layers, packers are used (Chapaev et al., 2006; Shumaev et al., 2020; Ovtov et al., 2021; Aksenov et al., 2020; Hevko et al., 2016). With high-quality pre-sowing tillage, skid coulters are most acceptable, as they are the simplest in design and reliable in operation, for fixing which it is better to use a parallelogram mechanism that allows you to copy the relief with high accuracy.
Therefore, the improvement of the working bodies of sowing machines, ensuring the implementation of the technological process corresponding to agrotechnical requirements, taking into account climatic conditions when cultivating small-seeded crops, is beyond doubt.

MATERIALS AND METHODS

At present, sowing of small-seeded crops is carried out with grain or grain-grass seeders.(SZ-3.6; SZT-3.6; SLT-3.6; SRN-4.2; SUPN-8; SST-8; SST-12A; SCON-4.2; CO-4.2; SOH -4.2SZU-5.4-06, etc.), which do not fully provide the required seeding rate, their placement in the soil layer at the optimal sowing depth of 2-3 cm. Therefore, pre-sowing rolling is used to evenly place seeds along the sowing depth in the soil horizon. The effectiveness of this technological technique is manifested if the rolling of ripe soil is carried out, then its structure will not be destroyed.
When sowing small-seeded crops, the creation of a dense bed for seeds plays an important role, since in this case, due to the influx of moisture from the lower layers of the soil and the optimum temperature, simultaneous germination of seeds occurs. The most favorable conditions for seed germination are when the seeds lie on a solid bed with a soil density of more than 1.2 g/cm^3, and they are covered with a loose layer of soil from above. In this case, the seeds lying on a hard bed receive moisture from the lower layers of the soil, and the upper, loose soil layer contributes to the penetration of oxygen to the seeds, their rapid germination and the friendly emergence of seedlings. It should be noted that the optimal condition of the soil for sowing small-seeded crops falls on its physical and biological ripeness.
Penza State Agrarian University has designed the design of a skid-shaped coulter with a furrow compactor, the three-dimensional model of which is shown in Figure 1 (RF patent No. 2738273 publ. 12/11/2020, Bull. No. 35), which allows to reduce the traction resistance of the sowing unit when sowing small-seed crops.

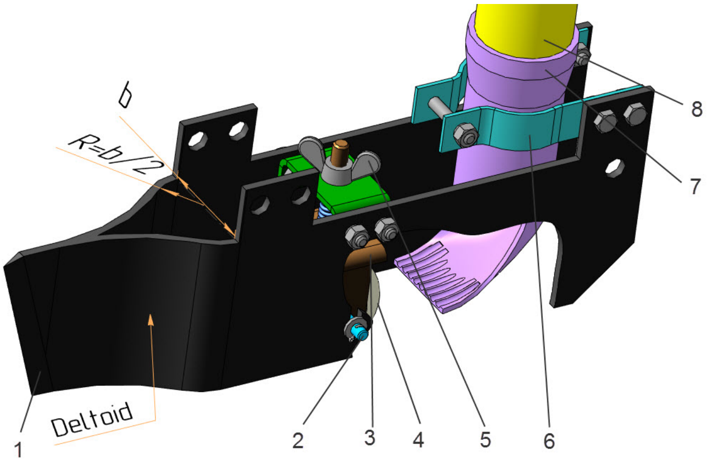


Figure 1. Coulter with furrow bottom compactor

RESULTS AND DISCUSSIONS

In the process of opener operation, in addition to the quality of the preparation of the landing furrow, its traction resistance is of no small importance.
The skid-shaped coulter consists of a cast body with cheeks 1, and the opening angle of the coulter cheeks is formed by flat algebraic curves - deltoids, and at the same time, the radius of deltoid rounding with the coulter cheek is 1/2 of the coulter width b, while the opening angle of the coulter cheeks β4 ... 6 degrees less than the double angle of friction of steel on the soil. On axis 2, installed in the cheeks of the coulter body, a seed bed-former 3 is hinged, with the ability to control the pressure force on the compacted soil with a roller 4 using a lamb nut 5. In the tail part of the coulter, using clamps 6, a receiving funnel 7 is attached, which also performs the function of a distributor seeds and having a curved surface made according to the brachistochrone with guide grooves of a curvilinear shape in cross section connected to the seed duct 8.
The operation of the coulter with the seed furrow compactor is as follows. When the seeder moves, the coulter (Figure 1), fixed on the sowing section, deepens and cuts the soil with a tip knife, simultaneously shifting the dry soil layer in both directions with its cheeks and opening a furrow (bed) in the wet layer. The roller compactor of the seed furrow bed, under the action of the loading spring, evenly compacts the bottom of the planting furrow, which favorably affects the attraction of moisture to the planting material through a network of capillaries formed in the compacted layer of the furrow. Seeds coming through the seed tube are evenly distributed along the grooves in the receiving funnel and sown evenly across the width into the compacted furrow.
During the tests during the movement of the sowing unit, weeds were observed to accumulate in front of the seeder coulter, which affects the quality of sowing. The conducted studies have shown the feasibility of using a skid-shaped coulter with an obtuse angle of entry into the soil.
The traction resistance of the skid coulter Fs will be the sum of its values for a wedge with an obtuse entry angle F_1, coulter jaws F_2, inertia forces of the ejected soil particles Fin and rolling friction force of the compacting roller Ftk (Figure 2) (Khudoberdiev et al., 2010; Shevchenko et al., 2013):

$$F_s = F_1 + F_2 + F_{in} + F_{tk}. \quad (1)$$

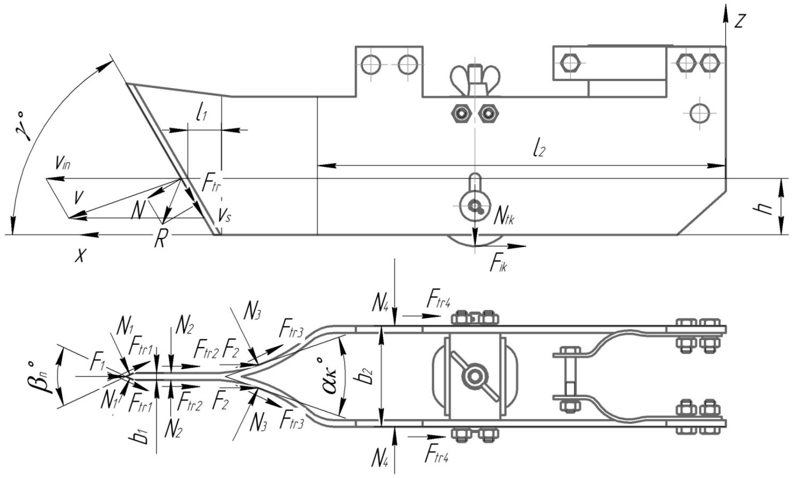


Figure 2 - Scheme acting on the coulter

The traction resistance of the runner coulter with a roller compactor of the bottom of the landing furrow was determined by the expression

$$F_s = q \cdot h \cdot b_1 + 2k \frac{b_1 h}{cos \frac{\beta_n}{2} sin\gamma} \cdot \frac{sin\,(\beta_n/2 + \varphi_{st})}{cos\varphi_{st}} + 2tg\varphi_{st} \frac{k \cdot l_1 \cdot h}{sin\gamma} + 2tg\varphi_{st} k \frac{b_2 h}{cos \frac{\alpha_k}{2}} + 2tg\varphi_{st} \times k \cdot l_2 \cdot h + \ b_2 \cdot h \cdot \rho \cdot v^2\, sin \frac{\alpha_k}{2} \cdot tg\varphi_{st} + 2 \cdot N_r \frac{\mu}{D},$$

where q is the specific cutting resistance of the soil, N/m^2; b1 is the thickness of the knife, m, h is the depth of the coulter in the soil, m;β_n - angle of sharpening of the knife blade, degree;φ_{st} - steel friction angle on the soil, degree; k is soil resistivity, N/m^2; l1 is the length of the side surface of the knife, m; b_2 - coulter body width, m; l_2 is the length of the side surface of the jaws of the coulter body, m;γis the specific gravity of the soil, N/m^3;α_k– opening angle of the cheeks of the coulter body, degree; v is the speed of the coulter, m/s; g is the free fall acceleration m/c^2; Nr - compacting capacity of a smooth roller (N/m^2)$\rho$is the volumetric mass of soil, kg/m^3; µ is the coefficient of rolling friction, m/N.

When the coulter moves, it is affected by the force of resistance to the introduction of the knife blade F_l and normal soil pressures on the blade N_1 and on the sidesurface of the coulter knife blade N_2 and side surfaces of the coulter body cheeks N_3 and N_4, soil friction forces on the knife blade fN_1, knife side surface f N_2 and soil friction forces on the coulter body cheek f N3, side surface of the coulter body cheek f N_4 (Figure 2).

Figures 3 and 4 show the theoretical graphical dependences of the traction resistance of the skid coulter depending on the speed of the seeder and the specific resistance of the soil.

The analysis of the presented dependences shows that with an increase in the speed of the sowing unit from 2.5 m/s to 4.72 m/s, the traction resistance of the skid coulter increases by 9.9%, and with an increase in the specific soil resistance from 6000 N/m^2 to 10000 N/m^2 the traction resistance of the skid coulter increases by 35.5% at a machine speed of 4.72 m/s. Thus, the obtained graphic dependences of the traction resistance of the skid coulter show that its traction resistance is more affected by the physical and mechanical characteristics of the soil, and not by the speed of the seeder during sowing.

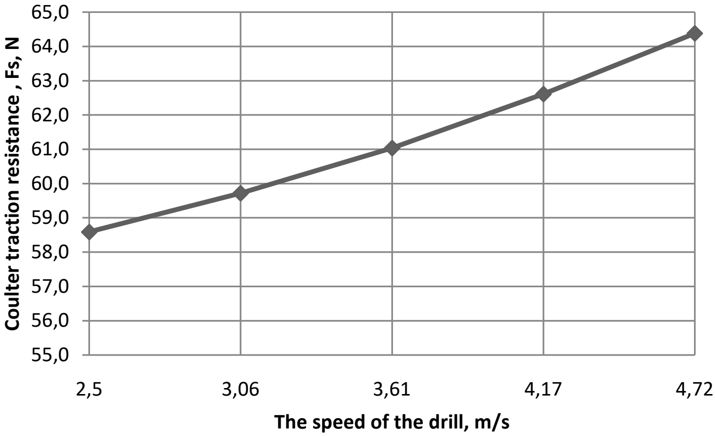
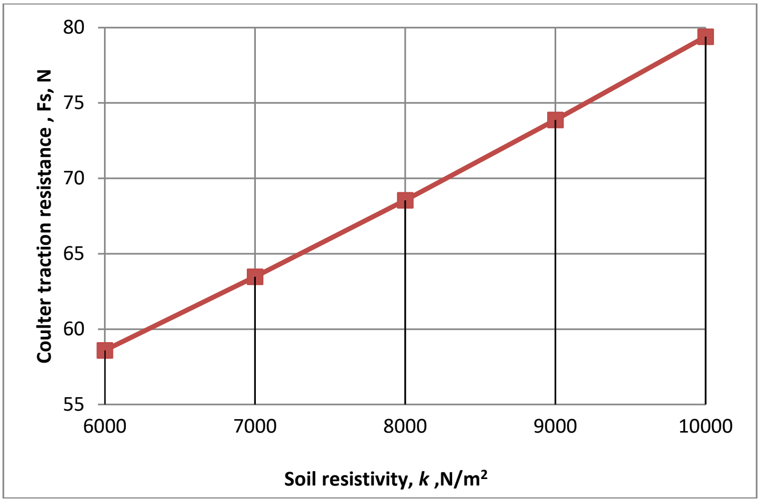


Figure 3 - Coulter traction resistance depending on the speed of the seeder



Picture 4 - Coulter traction resistance depending on soil resistivity

CONCLUSIONS

The design of the developed skid coulter with a roller compactor of the bottom of the seed furrow is proposed, and a theoretical substantiation of its traction resistance is made. The equipment of the seeder with this coulter reduces its traction resistance, which affects the reduction of fuel consumption and the reduction of exhaust gases into the atmosphere, in addition, the quality of the preparation of the seed furrow for sowing small-seeded crops improves, which makes it possible to increase their germination, and consequently the quality and productivity of the cultivated crop.. Also due to the uniform emergence of small-seeded crops, weeds will self-clog with cultivated ones, resulting in a reduced need to use herbicides, which will lead to environmentally safe production of crops.

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