Analysis of Work Process of Seeding Furrows Embedding by a Conical Roller

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Abstract: In the article the results of analysis of work process of seeding furrows embedding and compaction of soil by the conical roller which is set at the angles α to direction of furrow, and also analytical expressions for definition of resistance force of the roller by moving and lateral force which provides a self-cleaning of soil, which sticks to its surface, are given.

Keywords: conical roller, furrow, shift, soil, compaction, force, friction, self-cleaning

Introduction
One of the important factors that affect field seed germination and simultaneous emergence of seedlings is a reliable contact with the soil. That end, in soil is formed at the same depth a seeding furrow with compactions bottom to which seeds are sown and immediately embedded by ground. However, it is greatly loosened that does not provide a reliable seed contact with the soil. The use of rollers for packing of crops gives positive results, but in moist soils they are sticking greatly. Herewith the special devices installed to clean the roller surface are ineffective.

Therefore there is a need to develop highly efficient technical means for seed embedding and to improve seeding methods, which would provide herewith a high field seed germination and simultaneous emergence of seedlings.

Analysis of the literature dedicated to development of highly efficient means for seed embedding and for improve seeding methods, for enhance the field seed germination and simultaneous emergence of seedlings shows that they are sufficiently studied [1,2,3,4,5,6,8]. Based on research by the authors developed and proposed to agricultural production an appropriate recommendation, in particular, to provide the required density of stems is proposed to increase the seeding rate by factor of 1.5 ... 2, and to prevent the breaking of the root system after seeding – use the packing of crops.

However, the analysis of work process of seeding furrows embedding by the conical roller and elements of the theory of their self-cleaning of soil, which sticks, in the literature are not given.

Material and Method
One of the reserves of increase of spiked cereals yield is to create optimal conditions for seed germination and for subsequent plant growth and development and therefore the formation of crop. However, this environment, for many reasons, is not possible to create always. Particularly acute this problem appears after a harvesting of late crops, when it is necessary to conduct the seeding, and the soil after plowing is not yet settled and it cannot sow the seed in fresh tilled soil because of breakage of the root system. So after plowing must be hold the necessary time of full soil self-compaction, which runs for 3 ... 5 weeks and this leads to delaying seeding.

To solve this problem, we have developed a new way of seeding of spiked cereals seed in fresh tilled soil with:

Rезюме: Наведено результати аналізу робочого процесу засипання посівних борозенок і ущільнення грунту конічним котком, установленим під кутом α до напрямку борозенки, а також аналітичні вирази для визначення сили опору котка при переміщенні та бічної сили, яка забезпечує самоочищення від грунту, що прилипає до його поверхні.

Ключові слова: конічний коток, борозенка, зсув, грунт, ущільнення, сила, тертя, самоочищення.

Разоміна
Одним з важливих факторів, що впливає на високу схожість насіння і появу дружніх сходів, є надійний його контакт з ґрунтом. Цю мету в міру вони формують на однаковій глибині посіву борозну з ущільненням дном, на яке висівають насіння і відразу ж його загортають грунтом. Однак вони є сильно розпущеними, що не забезпечує надійного контакту насіння з ґрунтом. Застосування котків для прикочування посівів дає позитивний результат, однак на зволожених грунтах вони сильно залипають.

А тому виникає потреба в розробці високоенергетичних технічних засобів для загortonня насіння та в удосконалення способів сівби, які забезпечили б при що високу відносність насіння та поява дружних сходів.

Аналіз літературних джерел, приурочених питанням розробки високоенергетичних технічних засобів для загortonня насіння та удосконалення способів сівби, підвищення польової схожості насіння та появи дружних сходів показав, що вони є достатньо вивчені [1,2,3,4,5,6,8]. На основі результатів досліджень авторами розроблені і запропоновані високопродуктивні виробничі рекомендації, зокрема з метою забезпечення необхідної густоти стеблостою пропонується збільшувати норму висіву в 1.5...2 рази, а щоб не допустити обрив кореневої системи після сівби – застосовувати прикочування посівів.

Однак аналіз робочого процесу загортання посівних борозен конічними котками, а також елементи теорії їх самоочищення від напилку ґрунту, в літературних джерелах не наведиться.

Матеріал і методика
Одним з резервів підвищення врожайності зернових колосових культур є створення оптимальних умов для проростання насіння та наступного росту й розвитку рослин і, відповідно, формування врожаю. Однак такі умови, у селі багатьох причин, не завжди вдається створити. Особлива гостро цей проблеми відбуваються після збирання пізньих культур, коли необхідно проводити сівбу, а грунт після оранки ще не осів і висів насіння у свіжозораний ґрунт не можна, оскільки відбувається обрив кореневої системи. Тому після оранки обов’язково витримують необхідний час для повного самоосідання ґрунту, який проходить протягом 3...5 тижнів, і самоочищення від зсуву насіння зернових колосових культур у свіжозораний ґрунт
stabilization of water-air regime in the topsoil during phase flowing-trough period from seed germination to the tillage and suggest tillage and sowing section with packing of crops [7]. Structural and technological scheme of this section is shown in Fig. 1.

Fig. 1 - Structural and technological scheme of tillage and sowing section for seeding seeds in fresh tilled soil with packing of crops

1 – ribbed roller; 2 – frame; 3 – strip; 4 – drawbar; 5 – push rod; 6 – spring; 7 – fertilizer funnel; 8 – conical roller

Its main working body is annular soil compactor furrow-making device. It consists of a rectangular frame 2, in which there are three ribbed rollers 1. Frame 3 is connected to the strip 3, which by means of radial drawbar 4 and push rod 5 with spring 6 is connected to the frame of sowing unit. Back of frame 2 in the center of each ribbed roller 1 is set a fertilizer funnels 7, coverers, shoe openers and conical roller 8, which is set at the angle α to the direction of furrow. It provides high-quality seeding furrows embedding and soil compaction.

RESULTS
Analysis of work process of such roller shows that it should take the form of a truncated cone and be directed by a smaller base of cone to direction of motion. For interpretation of the interaction of roller with soil and swath we consider the scheme of work of conical roller in the vertical and horizontal planes, Fig.2 a,b.

Fig. 2 - Scheme of the forces acting on the conical roller

1 – roller; 2 – swath; 3 – furrow

Основним її робочим органом є кільцевидний ущільнювач-борознооутворювач. Він складається з прямокутної рамки 2, в якій встановлено три кільчастих котки 1. Рамка з’єднуються з штабою 3, яка за допомогою радіального повідка 4 і натисної штанги 6 з пружиною 6 з’єднується з рамою посівного агрегату. Заду рамки 2 по центру кожного кільчастого котка 1 встановлено тукопроводи 7, загортачі, килевидні сошники та конічний коток 8, установлений під кутом α до напрямку борозенки. Він забезпечує якісне засипання посівних борозенок і ущільнення грунту.

РЕЗУЛЬТАТИ
Аналіз робочого процесу такого котка показує, що він повинен мати форму зрізаного конуса і бути спрямованим меншою основою до напряму руху. Для виявлення взаємодії котка з грунтом і валком розглянемо схему роботи конічного котка у вертикальній і горизонтальній площинках, рис.2а,б.
Fig. 2 - Scheme of the forces acting on the conical roller
1 - roller; 2 - swath; 3 - furrow

From the scheme (Fig.2c) can be seen that gravity force of roller \( mg \) (here \( m \) - weight of roller, \( g \) - gravitational acceleration of the body) cause the frictional force of the roller against the soil:

\[
F_i = f_m g
\]  

(1)

where \( f \) - coefficient of friction of the roller against the soil.

This force is directed opposite to the direction of rollers rolling.

From the scheme is also seen that at point \( A \) of contact of rollers rim with swath appears a normal force \( N \), which declined from the vertical at the angle \( \gamma \) and it cause at this point the frictional force:

\[
F_2 = f \cdot N
\]  

(2)

We expand the normal force \( N \) on the components - horizontal:

\[
N_x = N \cdot \sin \gamma
\]  

(3)

and vertical:

\[
N_y = N \cdot \cos \gamma
\]  

(4)

Analysis of the forces components shows that the horizontal force moves the swath in direction of the velocity vector \( v \), and the vertical force - compact the swath and cause the friction force:

\[
F_3 = f_1 \cdot N_y
\]  

(5)

which is directed opposite to direction of the velocity vector \( v \) (here \( f_1 \) - coefficient of friction of the swath against the soil surface).

From the scheme on Fig.2c can be written condition of swath moving by the roller:

\[
F_1 = f_1 \cdot N_y
\]  

(5)

where \( f_1 \) - coefficient of friction of the swath against the soil.

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From the scheme on Fig.2c can be written condition of swath moving by the roller:
Using expressions (1), (2), (3), (4) and (5) the last inequality can be written in this form:

\[ F_1 + F_2 \cdot \cos \gamma + F_3 < N_f. \]

In terms of ensuring of swath shift in seeding furrow and of efficient self-cleaning rollers surface from stuck-on soil it is of great interest the projection of the normal force \( N \) in the horizontal plane \( N_H \) (Fig. 2b). From the above scheme is seen that this force causes the lateral force \( F \), which shifts the swath in the furrow and completely covering the seed with soil. Thus the lateral force provides the rollers self-cleaning from the soil that sticks to the surface. Its value can be determined by the formula \( F = f \cdot N_f \), which with account of expressions (3) and (8) takes on the following form:

\[ F = f \cdot N \cdot \sin \gamma = f \cdot \sin \gamma \frac{mg}{\cos f + \sin f \cdot \sin \gamma}. \]

To determine the draught of the roller we turn to the scheme of forces (Fig. 2b), which act from the direction of swath on the roller in a horizontal plane. From the above scheme is seen that the resistance force of the swath is determined by the following formula:

\[ Q = R_y + F \cdot \sin \alpha, \]

where \( R_y \) - projection of the resultant resistance force \( R \) of the swath along the axis \( OY \):

\[ R_y = R \cdot \cos \psi = R \cdot \cos(\alpha - \varphi) \]

here \( \psi \) - the angle between the resultant resistance force \( R \) of the swath and its constituent \( R_y \);

\( \varphi \) - angle of deflection of resultant resistance force \( R \) of swath from the normal force \( N_f \) which is equal to the rollers angle of friction against the swath;

\( \alpha \) - angle between the normal force \( N_f \) and direction of movement of the roller.

Given that \( R = \frac{N_f}{\cos \varphi} \), and the value of the force \( N_f \) is defined by the formula (3), expression (11) can be written as:

\[ R_y = \frac{N_f \cdot \sin \gamma}{\cos \varphi} \cos(\alpha - \varphi), \]

which in view of expressions (8) takes the form:

\[ R_y = \frac{mg \cdot \sin \gamma}{\cos f + \sin f \cdot \sin \gamma} \cos(\alpha - \varphi) \cos \varphi \]

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which in view of expressions (8) takes the form:

\[ R_y = \frac{mg \cdot \sin \gamma}{\cos f + \sin f \cdot \sin \gamma} \cos(\alpha - \varphi) \cos \varphi \]
We substitute the obtained values of \( R_v \) and \( F \) in expression (10), and get the draught resistance of the roller

\[
Q = \frac{mg \cdot \sin \gamma \cdot \cos(\alpha - \phi)}{\cos \gamma + f \cdot \sin \gamma} \cdot \cos \alpha + f \cdot \sin \alpha \cdot \frac{mg}{\cos \gamma + f \cdot \sin \gamma}
\]

which finally is written as:

\[
Q = \frac{mg}{\cos \gamma + f \cdot \sin \gamma} \cdot \sin \gamma \left[ \frac{\cos(\alpha - \phi)}{\cos \phi} + f \right]
\]

(13)

Value of the angle \( \gamma \) of the line of frictional force action \( F_2 \) of roller against the swath of soil we define as follows: We substitute in expression (6) instead of \( mg \) the expression (7) and obtain the inequality:

\[
fN(\cos \gamma + f \cdot \sin \gamma) + fN \cdot \cos \gamma + f_1N \cdot \cos \gamma < N \cdot \sin \gamma
\]

which after reduction on \( N \) can be written as follows:

\[
f \cos \gamma + f^2 \cdot \sin \gamma + fN \cdot \cos \gamma + f_1 \cdot \cos \gamma < \sin \gamma
\]

After the arithmetic operations can be written as:

\[
\cos \gamma (2f + f_1) < \sin \gamma (1 - f^2)
\]

where we define the angle \( \gamma \) of the line of frictional force action \( F_2 \) of roller against the swath

\[
\gamma > \arctg \frac{2f + f_1}{1 - f^2}
\]

(14)

Calculations show that for light soils by \( f=0.5 \) and \( f_1=1.0 \), we have \( \gamma > 63^0 \), and for heavy soils by \( f=0.8 \) and \( f_1=1.0 \), we have \( \gamma > 82^0 \).

Knowing the angle \( \gamma \) and the height \( h \) of the swath we can determine the minimum allowable rollers diameter. To do this, we consider the triangle \( AOB \) (Fig. 1b) from which we can write that \( OB = r \cdot \cos \gamma \), \( r - OB = h \). Therefore \( r - r \cdot \cos \gamma = h \) and \( r(1 - \cos \gamma) = h \), or \( \frac{D}{2} (1 - \cos \gamma) = h \), whence

\[
D = \frac{2h}{1 - \cos \gamma}
\]

(15)

Given that by the seeding of spiked cereals seed the shoe openers forming the swath height max 6 ... 10 cm, the rollers diameter should be 15 ... 35 cm.

CONCLUSIONS

1. During moving a conical roller which is installed at the angle \( \alpha \) to the direction of seeding furrow on its surface generator arises a lateral force \( F \), which shifts the swath in the furrow and completely covers the seed with the soil.

2. Efficient self-cleaning of the conical roller of soil that sticks to its surface is provided by the lateral force \( F \).

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