THEORY OF TWO-DISC ANCHOR OPENER OF GRAIN DRILL

ТЕОРИЯ ДВУХДИСКОВО АНКЕРНОГО СОШНИКА ЗЕРНОВОЙ СЕЯЛКИ

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Abstract: *High seeding quality of grain crops under modern technologies causes increase of requirements to seeders opener. We developed a new design of the combined two-disk anchor opener which can qualitatively carry out their functions under modern technologies, in particular no-till. Research purpose is development of the functioning theory of the created new furrow-opener design which integrates in itself constructive elements of two-disk openers and anchor type openers and can works on roughly prepared soil with plant residues and provides the stable seeds sowing depth at the increased seeding speeds. When carrying out researches methods of mathematics, theoretical mechanics, modeling, researches results statistical analysis, drawing up programs for calculations on PC are used. Parameters of the combined two-disk opener with the advanced mechanism of sowing depth regulation are substantiated. On the basis of the scheme of a opener design it is proved need of using certain rigidity spring for stability seeding to a predetermined depth within the agrotechnology limit. Dependences for calculation of rational spring elasticity which take into account geometrical parameters of opener design are obtained. The pilot studies conducted in field conditions confirm advantages of new constructive decisions of this combined opener. It is established that the seeder with the combined two-disk anchor openers steadily puts seeds on a compacted seed bed that excludes inertial seeds ejection beyond the agrotechnology limits, including at the increased seeding speeds.*

KEYWORDS*: SEEDING MACHINE, COMBINED OPENER, DESIGN, SEEDING, EQUIVALENT SCHEME, THEORY, SPRING*

1. Introduction

Effective functioning of grain drills and high quality of performance of technology process guarantees receiving heavy yields. Uniformity of seeds distribution at a necessary depth is the main requirements at selection of opener type. Under production conditions and in selection and seed-growing practice apply seeders with two-disc openers which do not provide stability of seeding of seeds on depth, especially at the increased sowing speeds of grain crops. Anchor openers stack seeds on the set depth, on a firm seed bed more evenly, but they use less often as they, unlike disk, require careful preparation of the soil. The existing technical solutions on creation of openers designs which provide seeding of grain crops seeds in the soil mulched by plant residues on stable depth, did not find broad practical application because of technology shortcomings and complexity of production. Improving the design of two-disc anchor opener unit is an important task. Seeds need to be placed in the soil at the set depth [9]. The accepted seeds planting depth for wheat, rye, oats, barley on light soil makes 4,5…6,0 cm, on average and wet 2,5…4,5 cm, heavy 2,0…4,0 cm, in a zone of wind erosion of 6…8 cm. The number of seeds, which is sown at a given depth, should not be less than 80% [3]. Selection openers group can ensure seed placement at the desired depth. The most universal opener for grain crops are two-disk openers [16] which are usually attached to a seeder housing on elastic radial suspension [13]. The main advantage of their application is the possibility of seeding on roughly processed lumpy soil with plant residues, openers cut or roll over obstacles. Two-disc openers are widely used in the traditional and minimal soil cultivation technologies. They are used on a moldboard background in seed drills of a model range SZ (JSC "Krasnaya zvezda") [8]. John Deere company manufactures grain drills 730, 455, 740A with two-disc coulters, which have a chamfer on the discs and with an staggered arrangement of openers. Two-disk openers are mounted on grain crop pneumatic seeders of Solitair of Lemken firms for work on the moldboard and mulch backgrounds, grain drills HT and CPH of Great Plain company are equipped with two-disc openers for direct seeding. [4]. Shortcomings of openers is that they do not meet agrotechnical requirements concerning creation of the compacted bottom of a sowing furrow and as a result do not provide for a seeds the necessary regime of humidity at the chosen depth [7]. In addition, this study demonstrated that these openers unevenly distribute the seeds on depth in a furrow. At a speed of seeder more than 8 km·h^{-1} a significant amount of seeds even brought to the surface of the field, at a given depth remained only 38…56% of seeds. At a deviation of depth of seeding of seeds by 18 mm their field germination rate decreases approximately to 54% [15]. Openers of keel-shaped type most naturally form a furrow and seedbed, provide a natural seed contact with the soil and provide the required depth of the seeding. They are convenient in that the quality of their work is less dependent on the speed, and it are not drags into the seed furrow crop residues, this type of opener can toss away a plant residues on both sides of furrow [14, 17], but this opener require careful preparation of the soil and is very sensitive to physical and mechanical state of soil.

2. Preconditions and means for resolving the problem

2.1. Analysis of recent research and publications

There are scientific works on improving design of a disk openers [1, 2, 15], as well as the development of simplified design which combines the advantages of two-disk and anchor types of openers [5, 10], technical solutions are not widely used in industrial practice and research really because of complexity of manufacturing and adjustment, as well as drawbacks typical of the two-disc openers. Therefore an actual task is creation of openers design for seeding of grain crops which provides increase of seeds planting depth stability and distribution them on a furrow bottom without contact of seeds with internal surface of the disks rotating at the movement of opener.

2.2. Purpose of the study

Research purpose is development of the functioning theory of the created new opener design which integrates in itself constructive elements of two-disk openers and anchor type openers and can works on roughly prepared soil with plant residues and provides the stable seeds sowing depth at the increased seeding speeds.

2.3. Materials and Methods

When carrying out researches methods of mathematics, theoretical mechanics, modeling, researches results statistical analysis, drawing up programs for calculations on PC are used.

3. Results and discussion

Modernization of the opener is to improve the design of combined two-disc coulters, which is equipped with keel-shaped part, hinged to the housing between discs, which enhances uniformity of depth of seeding seeds by eliminating lifting the low tip part to a height that exceeds agrotechnological tolerance. The problem is solved by the fact that the design of opener, which accommodates mounted with possibility of rotation by a corner in the direction along the opener movement, two flat discs and disposed between discs opener housing, and between the disks via a hinged suspension and spring to its housing attached keel-shaped part that holds socket and opener tip. Installing opener keel-shaped part between disks by attaching it to housing via a hinged suspension and springs allows tip of opener to move in the prepared furrow previously opened by disks and to compact a bottom of seed bed. In this case a seed does not contact to the rotating surfaces of disks that exclude moving of seeds with a soil to upper layers of furrow and increases depth stability of seeding.

The advantages of two-disk and keel-shaped openers are joined in design of combined opener [11]. On a structural scheme Fig. 1 of the combined two-disk anchor opener shows: *a* – side view at the removed left disk; *b* – section along A-A in enlarged size.

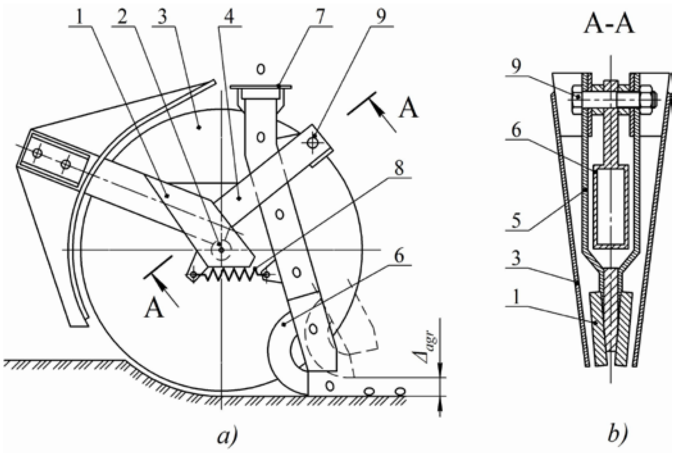

Fig. 1. *Structural scheme of the combined two-disk anchor opener: a) – side view when removing the left disk; b) – section along A-A: 1 – case; 2 – axle; 3 – disk; 4 – holder; 5 – plate; 6 – opener tip; 7 – socket; 8 – spring; 9 – hinged suspension*

Opener consists of a housing 1, wherein on the axes 2 with possibility of rotation two flat disks 3 are installed with angle to a moving direction. Between disks is placed holder 4 that consists of two plates 5 which is connected to the body. In space between the plates 5 is mounted keel-shaped part of combined opener which has a socket 6 and tip 7, and is attached to housing 1 by a spring 8, and to the holder's plates - by means of a hinged suspension 9, which is located behind keel-shaped part.

Combined two-disk anchor opener works as follows: when the opener moving discs 3 rotate on the axes and open seed furrow, installed in the space of the holder 4, formed by the plates 5, and hanging by a hinged suspension 9 keel-shaped opener by spring 8 is pressed against the lower of the tip 7 toward bottom of seed furrow and compacts it.

To ensure seeding depth stability and determination of parameters of combined two-disk anchor opener for the mathematical description of its movement in the soil is necessary to analyze the scheme of forces that act on it during movement, without taking into account inertia forces. Consider the design of a new the opener as balanced system, similar to the design of the prototype [6], and an appropriate equivalent power scheme which is shown in Fig.2.

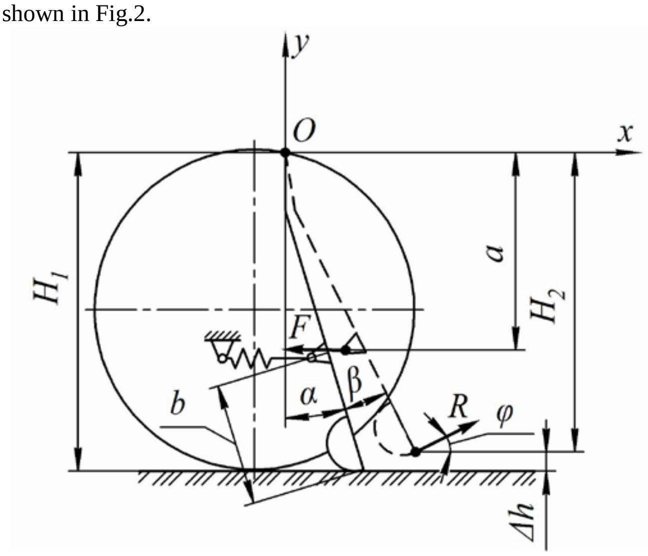

Fig. 2. *Equivalent scheme of the combined two-disk anchor opener*

The scheme (Fig. 2) shows main force characteristics of the opener constructive elements: H_1 – distance from the axis of hinge suspension to the bottom of seed furrow; H_2 – seeding depth with a maximum deflection; a, b – constructive parameters of the opener; β – deflection angle of seeds movement; φ – deflection angle of soil resistance force directions from the horizontal; R – soil resistance force; Δh – change in the depth of sowing seeds; F – spring elasticity force.

Hinged suspension 9, respectively to improved design (Fig. 1a) attached to the casing 1 and connected to the opener holder 4, which consists of two plates 5, which create a space in which a keel-shaped member was placed. The axis of hinge suspension keel-shaped member located behind the opener axis according to the movement direction. Projection of the hinge suspension axis to the bottom of the seed furrow coincide with the contact zone lower part of tip 7 and bottom of seed furrow. Distance from the hinge suspension axis to the bottom of seed furrow H_1 selects from the following relationship:

$$H_1\left(1-\cos\beta_{\max}\right)=\Delta h<\Delta agr. \qquad (1)$$

where: β_{max} – maximum deflection angle of keel-shaped part from the axis of hinge suspension; Δ_{agr} – value of agro technical limit for a depth of seed placement.

We write the equation of equilibrium with a maximum deviation of seeding as the equality to zero moments of forces that act on the system, relative to the point *O* of the hinge suspension (Fig. 2):

$$\begin{gathered}-F\cdot a\cdot\cos\beta+R\cdot\sin\varphi\left[a\cdot\sin\beta+b\cdot\sin\left(\alpha+\beta\right)\right]+\\+R\cdot\cos\varphi\left[a\cdot\cos\beta+b\cdot\cos\left(\alpha+\beta\right)\right]=0.\end{gathered} \qquad (2)$$

From the equilibrium equation (2) we obtain expression for finding the elasticity of the spring force:

$$\begin{gathered}F=\frac{R\sin\varphi\left[a\cdot\sin\beta+b\cdot\sin\left(\alpha+\beta\right)\right]}{a\cdot\cos\beta}+\\+\frac{R\cos\varphi\left[a\cdot\cos\beta+b\cdot\cos\left(\alpha+\beta\right)\right]}{a\cdot\cos\beta}.\end{gathered} \qquad (3)$$

With a small angle of rotation β the value of the spring stretch can be taken as:

$$\Delta x=a\cdot\sin\beta\,. \qquad (4)$$

We find the relationship between the value of spring stretch and deviation of stroke depth:

$$\Delta h=H_1-H_2\,. \qquad (5)$$

We find that

$$H_1 = a + b \cdot \cos\alpha \ , \qquad (6)$$

and

$$H_2 = a + b \cdot \cos(\alpha + \beta) \ , \qquad (7)$$

Defining deviation of stroke depth:

$$\Delta h = b\left[\cos\alpha - \cos(\alpha + \beta)\right] . \qquad (8)$$

Let us transform expression (8):

$$\Delta h = b\left[\cos\alpha - \cos\alpha \cdot \cos\beta + \sin\alpha \cdot \sin\beta\right] ,$$

$$\Delta h = b \cdot cos\alpha(1 - cos\beta) + b \cdot sin\alpha \cdot sin\beta \ ,$$

$$\sin\beta = \frac{\Delta h - b \cdot \cos\alpha(1 - \cos\beta)}{b \cdot \sin\alpha} \ . \qquad (9)$$

Substituting in the formula (9) depth tolerance Δh as well as the value of *a*, *b* and *α* possible to calculate the value of acceptable deviation angle.

Substituting (9) into the formula (4), we obtain the value of the maximum spring stretching:

$$\Delta x_{max} = a\frac{\Delta h - b \cdot cos\alpha(1 - cos\beta)}{b \cdot sin\alpha} \qquad (10)$$

Taking into account expressions (4) and (11) we can calculate the spring stiffness *k* when value of the deviation is within the agrotechnical tolerance:

$$k = \frac{F}{\Delta x_{\max}} \qquad (11)$$

The results of calculations carried out on the PC in Mathcad environment by formula (11) indicate that if geometrical parameters of the opener a = 120 mm, b = 220 mm, α = 15 °, β = 10 ° when maximum spring stretching is Δx = 14 mm.

To overcome soil resistance force on the opener which is equal to 100 N with angle of friction of knife on the surface of the soil φ = 45° according to formula (3) spring must overcome the force F = 258 N. Thus, the spring stiffness by the formula (11) must be equal to $k = 258 / 0,014 = 1,8 \cdot 10^4$ N·m^{-1}.

4. Conclusion

1. As a result of theoretical and experimental studies substantiated parameters of combined two-disk anchor openers and field trials of manufactured samples was carried out. During field testing it found that due to the retrofitting two-disc openers by additional keel-shaped part the combined two-disk anchor openers steadily puts seeds on a compacted seed bed that excludes inertial seeds ejection beyond the agrotechnology limits, including at the increased seeding speeds. The main advantages of the proposed openers were defined.

2. Carried out on PC calculations found that in order to overcome the soil resistance force on the opener knife for fixed its value and knife friction angle on the soil surface spring must overcome the force F = 258 N. In this case, the spring stiffness should be not less than $k = 258/0,014 = 1,8 \cdot 10^4$ N·m^{-1}.

5. Literature

1. A.s. №1688796 SSSR A01C7/20 Soshnik / A.P. Kolomiets; №4724434-15; zayavl. 27.07.91; opubl.07.11.91, Byul. № 41.

2. A.s. № 1273006 SSSR, pat. №7780UA A01C7/20 Soshnik / V.A. Nasonov; V.A. Zyiryanov; I.I. Zaytsev; M.S. Homenko № 3911802/ SU; zayavl. 19.05.85; opubl. 26.12.95, Byul. № 4.

3. Vasilchenko V. Faktoryi, kotoryie opredelyayut kachestvo poseva / V. Vasilchenko, V. Opalko // Agronom. – 2011. – №1. – S. 186 – 189.

4. Vasilchenko V. Soshniki zernovih sivalok: osoblivosti budovi ta tiporozmiri / V. Vasilchenko, O. Tkachenko, N. Vorontsova // Agronom. – 2010. – №4. – S. 140 – 146.

5. Gorobey V.P. Issledovanie dvuhdiskovogo kombinirovannogo soshnika dlya polosovogo vyiseva semyan / V.P. Gorobey., V.A. Luzin // Vestnik agrarnoy nauki. – 2010. – №10. – S. 74 – 76.

6. Gorobey V.P. Opredelenie zhestkosti pruzhinyi kombinirovannogo dvuhdiskovogo ankernogo soshnika / V.P. Gorobey // MESH. – 2015. – №1. – S. 7 – 9.

7. Dmitriev A.L. Sovremennoe selskohozyaystvennoe mashinostroenie v SShA, Anglii i v nekotoryih drugih kapitalisticheskih stranah / A.L. Dmitriev // Mehanizatsiya selskogo hazyaystva. sb. perev. i obzor. inostr. literaturi; otv.red. A.V. Chumak. – Moskva. Izd. inostr. literaturyi. 1955. – S. 5 – 66.

8. Levchuk M. Mashini dlya poseva / M. Levchuk, V. Ziryanov // Farmer. 2007. – №4. – S. 36 – 38.

9 Karpenko A.N. Mehanizatsiya polevodstva; pod red. A.N. Karpenko. – M.: Gos. izd.s.-h. literaturyi. – 1958. – 533s.

10. Pat. 88696 UA A01C7/00 Soshnik dlya polosnogo vyiseva zernovyih kultur / V.P. Gorobey; V.A. Luzin; A.L. Krasnichenko – № 200714097; zayavl.14.12.97; opubl. 10.11.99; Byul. № 21.

11. Pat. 93837 UA A01C2/00 Dvodiskoviy kombinovaniy soshnik / V.P. Gorobey; V.A. Luzinta ta in. – № a201006315; zayavl. 25.05.10; opubl. 10.03.11; Byul. № 5.

12. Peday N.P. Kompleksnaya mehanizatsiya selektsionno-opyitnyih rabot v Rossii / N.P. Peday / Materialyi 12-y vsemirnoy konferentsii po mehanizatsii polevyih eksperimentov. – Moskva. FGNU “Rosinformagroteh”, 2004. – S. 50 – 57.

13. Pogorelyiy V. U kazhdogo soshnika svoi koziri / V. Pogorilyiy, L. Shustik, S. Marinin // Zerno – 2011. – №2. – S. 90 – 92.

14. Sakston K.E. Glavnyiy element siyalki / K.E. Sakston // Zerno. – 2007. – №3. – S.97 – 105.

15. Sisolin P. Zabezpechennya optimalnih norm visivu zernovih kultur za rahunok yakosti zagortannya nasinnya / P. Sisolin // Tehniko-tehnologichni aspekti rozvitku ta viprobuvannya novoYi tehniki i tehnologiy dlya silskogo gospodarstva UkraYini. UkrNDIPVT. Vipusk 6(20). Kniga 1. Doslidnitske. 2003. – S. 68 – 72.

16. Bosoy E.S. Teoriya, konstruktsiya i raschet selskohozyaystvennyih mashin: Uchebnik dlya vuzov selskohozyaystvennogo mashinostroeniya / E.S. Bosoy, O.V. Vernyaev, I.I. Smirnov i dr.; pod. red. E.S. Bosogo – 2-e izd., pererab. i dop. – Moskva: Mashinostroenie, 1978. – 568 s.

17. Shmat S.I. Mozhlivosti pidvischennya yakisnih pokaznikiv dvodiskovih soshnikiv / S.I. Shmat, V.A. Reznichenko // Tehnika v silkogospodarskomu virobnitstvi, galuzeve mashinobuduvannya, avtomatizatsiya. – Vipusk 17. KNTU. – 2006. – S. 79 – 81.