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DETERMINATION OF PARAMETERS OF THE MAIN DISTRIBUTOR FOR FERTILIZER APPLYING MACHINE

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Abstract

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For a uniform distribution of mineral fertilizer on sowing openers by main distributor it is necessary, firstly, to ensure a stable distribution law of particles in a cross-section of material supply tube on the input to a working body. Then propose a mode for dispersion of loose material with stable characteristics. The first problem is solved by introduction of a turn (bow section) in transportation tube, and the second problem by installation of quadruple helical spiral with linear shift of the beginning of winds as a whirler in a stream of moving material. The shifts of winds' beginnings and velocities of particles are theoretically justified in horizontal transportation sites, at bow section (turn on 90˚), in a whirling zone and in a vertical section - before a dividing head which serve for calculation of their design data.

Key words: main distributor, material supply tube, mineral fertilizers, helical spiral

Introduction

Increase of volume of gross output in agriculture always puts a problem of raising effectiveness of machines and equipment, including cultivators with fertilizer distributors, which play an important role in system of agricultural works mechanisation. Efficiency of their work is in many respects defined by quality of distribution of the fertilizers provided by sowing system.

Among the existing sowing systems the greatest attention is to be paid to pneumatic transportation of fertilizer granules with their centralised dispensing, allowing introducing power and resource saving technologies in agriculture. However the existing pneumatic systems with vertical distributors cannot always fulfil agrotechnical requirements on uniformity of fertilizers distribution over material supply tubes (Schumann, 2010; Schumann et al., 2010; Cakmak et al., 2010).

In this connection, quality improvement of fertilizers distribution over supply tubes, by substantiation of design and technological parameters of a distribution unit of a pneumatic cultivator with fertilizer distributor is a topical task. It can be solved by providing a stable distribution law of fertilizer granules in the cross-section of a material supply tube at the input of a working body which will ensure uniform distribution of loose material.

Problems of the existing distributor models

Dispense by stud-roller feeds fertilizers flow through supply tubes to the furrow bottom forced by gravity. To ensure the uniform outflow of fertilizers the supply tubes should be mounted on the machine without distortions and high enough to exclude their tilt. Fulfillment of this condition demands considerable height of installation of fertilizer tanks and limits operating width of the machine (to 4 m) (Nefyodov, 1991). In this case modular construction of the unit is expedient.

Devices for distribution of a loose material are widely used in mining industry, in agricultural production - for entering of seeds and mineral fertilizers into soil, preparation of mixed fodders, etc. The basic requirement to such devices is distribution of a stream to parts in necessary, more often in equal, proportions. However, dividers cannot always ensure high quality of distribution of loose materials with different physical and mechanical properties (Asmolov, 1995; Ben Salem and Oesterle, 1998; Bird, 1994; Crowe et al., 1995,

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Crowe et al., 1996, Crowe et al., 1998; Kurose and Komori, 1999; Oesterle and Bui Dinh, 1998; Osiptsov, 1997, Osiptsov, 2000; Osiptsov et al., 2002; Sommerfeld, 1993a; Sommerfeld, 1993b; Sommerfeld et al., 1993; Tsirkunov et al., 1994a; Tsirkunov et al., 1994b).

Fertilizers flow to the distribution unit by gravity or are transported by air stream. The design of a working body of the device, whenever possible aligns flow density of the supplied material in the cross-section of supplu tube, and then it gets to a divider. It divides supply tube's cut into the equal platforms which number corresponds to the number of offsets or is multiple of it.

The mechanical operation of a divider comes down to density distribution, i.e. enrichment of the depleted sites at the expense of particles from the most condensed sites in the cross-section of material supply tube.

The distribution law of the material passing through the same cross-section of the supply tube is random and depends on many factors: kinematics of operation mode, configuration of material supply tube, physical and mechanical properties of the material, the construction design, etc. (Zuev, 1974). For the examination of distribution of material in material supply tube (Figure 1) three extreme variants of material concentration on an input (line 2) and an output (line 4) which cross-section is conditionally divided into four sectors are considered.

Suppose the device design accurately and reliably moves a part of a material from sectors I and IV to sectors II and III (line 2, column 3). Following variants are available:

Variant A. The part of loose material from enriched sectors I and IV gets to sectors II and III. On the output from the working body the material is evenly distributed in the cross-section of material supply tube (line 4, column 3).

Variant B. If evenly distributed on the cut material is treated (line 2, column 4), the device oppositely raises non-uniformity on the output (line 4, column 4), i.e. its operation is opposite to the requirement.

Variant C. The considered device operates in the similar way with treating the material of concentration C (line 2, column 5).

The aforesaid shows that quality of distribution on the output of material supply tube can be raised, only at one or a proximal distribution law of the material at the input, for example by variant A.

From here a conclusion: action on the loose material, stabilizing the law of its distribution at the input of a working body is necessary.

For this purpose, at first, it is necessary to ensure an establishment of the stable distribution law of particles in the cross-section of the material supply tube. Secondly, to discover a mode and to design the device for separation of loose material with already stable indicators. By these means only it is possible to achieve a stable process with high reliability of results.

Design solution

For a solution of the first problem an action on kinematics of the stream before its inflow in the working body is pro-

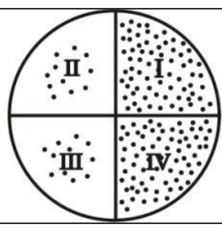
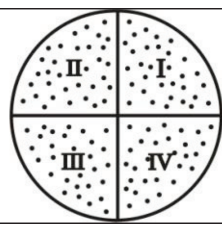
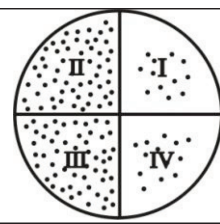
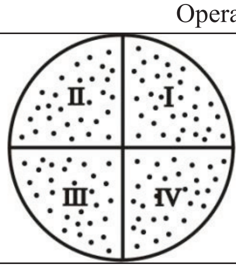
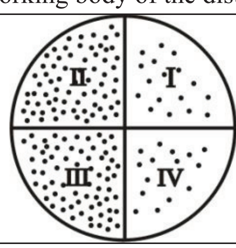
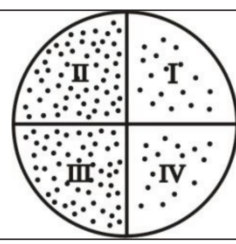
№	Variants			
		A	B	C
1	2	3	4	5
2	Input			
3	Operation of a working body of the distributor			
4	Output			

Fig. 1. Distribution of a loose material in material supply tube

posed (Figure 2). With that end in view the site of turn 2 is introduced into a line 1. Thus centrifugal forces concentrate particles on the outer side of a site of turn, cut C-C. This law is steady and it will be not influenced by the above-stated factors, especially it is important in mobile installations.

Further the stabilized stream of material has to be swirled. For this purpose after the turn site the additional constructive element - the swirler 3 is installed, in the form of a screw spiral and occupying all cross-sections (Patent 19007 RK, 2008). The stream reaching the screw spiral swirls. Owing to a rotation under the influence of inertia centrifugal forces, it spreads over interior wall of the material supply tube and distributes on it by an equal stratum, taking the form of a hollow cylinder in cross-section B-B (Figure 2). Stably concentrated stratum of the material in a cross-section of the body of the distributor is mechanically divided by winds into identical parts and receives a rotation, creating a stream in the form of a rotating ring that promotes their uniform distribution.

The device accomplishes the double operation directed on a rectangular distribution of a material on cut:

- Mechanical - the motionless spiral winds;

- Kinematic - from the influence of centrifugal forces of inertia.

Such design of the body of the distributor and screw disposition allows lowering influence of oscillations, verticality deviations of the distributor, rolling and other casual actions on quality of work.

Experimental research has shown that application of a whirler with single-start spiral winds does not give desirable outcome. Good outcomes are received at application of 4-starts spiral. However the action of only centrifugal forces of inertia of the material is not enough for shaping the stream into the form of a rotating ring. Particular complexity is in concentration of the material in the lower part of the material supply tube at horizontal and in the outer side of curving at vertical transportation.

For the solution of this problem the whirler is proposed, ensuring not only the stream whirling, but also mechanically dismembering it on equal parts with the subsequent creation of a rotating ring (Nukeshev, 2009). It is achieved by linear shift of the beginning of winds on generatrix of the material supply tube (Figure 3).

Mathematical investigation

For substantiation of shift values *c* the process of material movement through the whirler winds is investigated (Figure 3). After passing the curve of the material supply tube, the material gets on the screw whirler which is shown in flat pattern in Figure 3. The length of an arc of the filled sector ABCDE and its unfolding $A_1B_1C_1D_1E_1$ are equal:

$$ABCDE = A_1B_1C_1D_1E_1 = \frac{\pi \cdot d}{360} \cdot \varphi \ , \qquad (1)$$

where *d* is diameter of the material supply tube; φ – central angle of filled sector.

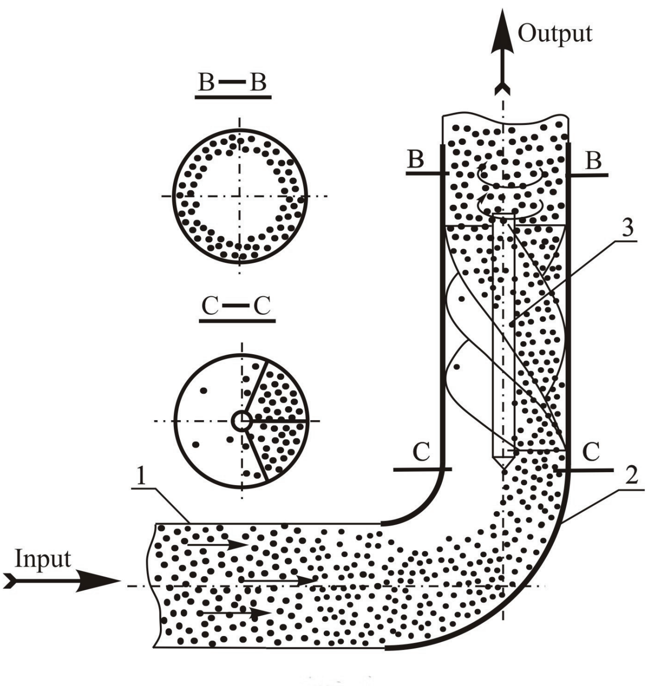


Fig. 2. Device for distribution of a loose material
1 – line section, 2 – turn section, 3 – spiral winds

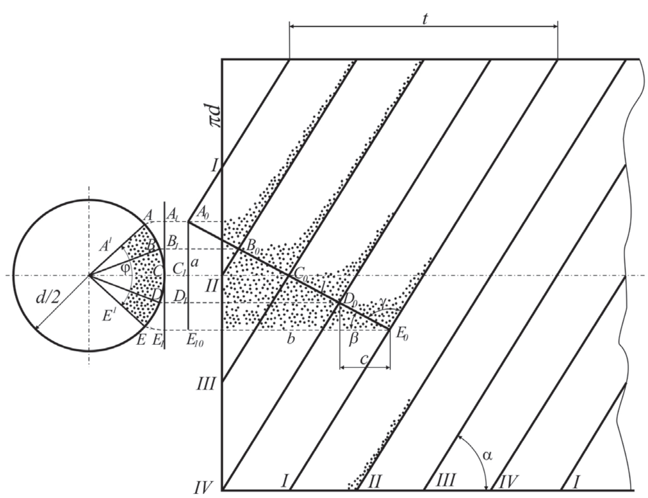


Fig. 3. Distribution of the material in cross-section of the whirler whit shifted winds and its unfolding

The length of the arc of the filled sector also can be expressed as:

$$AE = A_1E_1 = \pi \cdot d \cdot z\,, \tag{2}$$

where z is degree of filling of the material supply tube concavity. It can have values: 1/2, 1/3, 1/4, that corresponds to angles φ: $\pi/2$, $\pi/3$ and $\pi/4$.

The right members of (1) and (2) can be equated:

$$\frac{\pi \cdot d}{360}\cdot\varphi = \pi \cdot d \cdot z\,;\ \varphi = 360\cdot z \tag{3}$$

For convenience of the further conclusions we accept symbols:

$A_0E_{10} = a$; $E_{10}E_0 = b$; $A_0E_0 = l$.

Use the theorem of sine:

$$\frac{t}{\sin\gamma} = \frac{l}{\sin\alpha}\,;\ l = \frac{t\cdot\sin\alpha}{\sin(\alpha+\beta)}\,,$$

where $\gamma = \pi - (\alpha + \beta)$, and t is the lead of spiral wind.

From Figure 3 it follows :

$$l = \frac{a}{\sin\beta}\,.$$

Having equated last two expressions the following is received:

$$\tan\beta = \frac{a\cdot\tan\alpha}{t\cdot\tan\alpha - a}\,. \tag{4}$$

From Figure 3 is also derived:

$$b = \frac{a}{\tan\beta}\,.$$

Using the expression (4):

$$b = t - \frac{a}{\tan\alpha}\,. \tag{5}$$

where the lead of spiral wind is $t = \dfrac{\pi\cdot d}{\tan\alpha}$, and $\alpha = \pi\,.\,d\,.\,z$. Then:

$$b = \frac{\pi\cdot d}{\tan\alpha}(1-z)\,. \tag{6}$$

Designating the number of starts of spiral winds n_s, the shift value equals to:

$$c = \frac{\pi\cdot d}{n_s\cdot\tan\alpha}(1-z) \tag{7}$$

Calculating the shift value for parametres: $\alpha = 60°$, $n_s = 4$; $d = 40$ mm; and $z = 1/4$.

$$\tilde{n} = \frac{3.14\cdot 40}{4\cdot\sqrt{3}}(1-\frac{1}{4}) = 13.61 \text{ mm.}$$

The received value precisely corresponds to the graphically constructed, on the accepted dimensions.

Transported by a stream of air material concentrated on the outer side of bow section of the distributor, is exposed to whirling and is mechanically divided by spiral winds, on delayed from each other parts. Passing a vertical site, the material arrives further to the dividing head where it is distributed on offsets which are arranged in the trajectory of movement of the material particles.

Depending on air velocity, certain influence on preservation of a rotating stream and its rectangular distribution on offsets, obviously, will be had by height of a vertical site. For its substantiation fertilizer movement on sites of the material supply tube is to be considered. The material supply tube can be divided into four sections - I, II, III, IV (Figure 4).

It is known that for maintenance of uniform movement of a liquid (gas) in the horizontal pipeline (section I) it is necessary to support pressure difference which is defined by Darcy-Weisbach equation:

$$\Delta p = p_1 - p_2 = \lambda\,\frac{l}{d}\cdot\frac{\rho\cdot\upsilon^2}{2}, \tag{8}$$

where ρ is density of the liquid (gas); λ – resistance factor; p_1 and p_2 – pressure in cuts 1 and 2; d and l – diameter and length of the material supply tube; υ – average velocity of the liquid; $\dfrac{\rho\cdot\upsilon^2}{2}$ – dynamic pressure.

In (8) it is possible to substitute λ with factor of aerodynamic resistance k_x and ratio l/d - with midsection area A_r. For a two-component stream dynamic pressure is calculated by means of a difference of velocities of each of the components. Thus force of aerodynamic resistance in the rectilinear pipeline from (8) looks like:

$$P_x = \frac{1}{2}k_x\cdot A_r\cdot\rho(\upsilon - u)^2, \tag{9}$$

where υ and u are the average velocities of two components of the stream.

In the horizontal pipeline on a firm component of a two-component stream the force of a friction also operates, proportional to normal pressure on the lower wall. Therefore, the differential equation of such stream on the section I looks like:

$$m\frac{du}{dt} = P_x - f\cdot N\ . \tag{10}$$

Taking into account (9) and having equated N on $m \cdot g$, it is received:

$$m\frac{du}{dt} = \frac{1}{2}k_x \cdot A_r \cdot \rho(\upsilon - u)^2 - f \cdot m \cdot g \qquad (11)$$

In the beginning of movement velocity of a firm component $u_0 = 0$, hence $\frac{du}{dt} = 0$. Then from the equation (11) it is derived:

$$\upsilon_0 = \sqrt{\frac{2f \cdot m \cdot g}{k_x \cdot A_r \cdot \rho}}, \qquad (12)$$

where υ_0 is initial velocity of the air stream at which the particle is in suspension.

Define k_x from (12) and substitute it in (11):

$$\frac{du}{dt} = f \cdot g\left[\left(\frac{\upsilon - u}{\upsilon_0}\right)^2 - 1\right] \qquad (13)$$

Solution of the equation (13) under initial conditions $u_0 = 0$ and $t_0 = 0$:

$$u_1 = \frac{\upsilon\left(e^{\frac{2q \cdot t}{\upsilon_0}} - \frac{\upsilon - \upsilon_0}{\upsilon + \upsilon_0}\right) - \upsilon_0\left(e^{\frac{2q \cdot t}{\upsilon_0}} + \frac{\upsilon - \upsilon_0}{\upsilon + \upsilon_0}\right)}{e^{\frac{2q \cdot t}{\upsilon_0}} - \frac{\upsilon - \upsilon_0}{\upsilon + \upsilon_0}} \qquad (14)$$

Equation (14) gives dependence of the velocity of a particle in the pipeline from its aerodynamic properties and transiting time on the pipeline. Knowing it, it is possible to calculate length of the.

For convenience of calculations factor of overfall of a velocity of an air stream is introduced:

$$\frac{\upsilon_0}{\upsilon} = \zeta .$$

Thus expression (14) becomes:

$$u_1 = \frac{\upsilon\left(e^{\frac{2q \cdot t}{\upsilon_0}} - \frac{1 - \zeta}{1 + \zeta}\right) - \upsilon_и\left(e^{\frac{2q \cdot t}{\upsilon_0}} + \frac{1 - \zeta}{1 + \zeta}\right)}{e^{\frac{2q \cdot t}{\upsilon_0}} - \frac{1 - \zeta}{1 + \zeta}} \qquad (15)$$

Consider section II. On a fertilizer particle the gravity $m \cdot g$, aerodynamic motive power $P_x = m\frac{du}{dt}$, normal pressure of a wall of pipeline N and force of a friction F_{fr} influence (Figure 5).

Equation of movement of a particle in system of natural axes n and t looks like:

$$\begin{aligned} \sum \tau &= P_x - F_{fr} - m \cdot g \cdot \sin\varphi = 0; \\ \sum n &= N - m \cdot g \cdot \cos\varphi - m\frac{u^2}{R_0} = 0. \end{aligned} \qquad (16)$$

From the second equation (16) it is discovered:

$$F_{fr} = f \cdot m\left(\frac{u^2}{R_0} + g \cdot \cos\varphi\right) \cdot \qquad (17)$$

Taking into account (17) and values P_x from the first equation (16) it is discovered:

$$\frac{du}{dt} = \frac{f \cdot u^2}{R_0} + f \cdot g \cdot \cos\varphi + g \cdot \sin\ \varphi \qquad (18)$$

Reduce (18) in angular co-ordinate φ:

$$\frac{du}{dt} = \frac{u}{R_0} \cdot \frac{du}{d\varphi} .$$

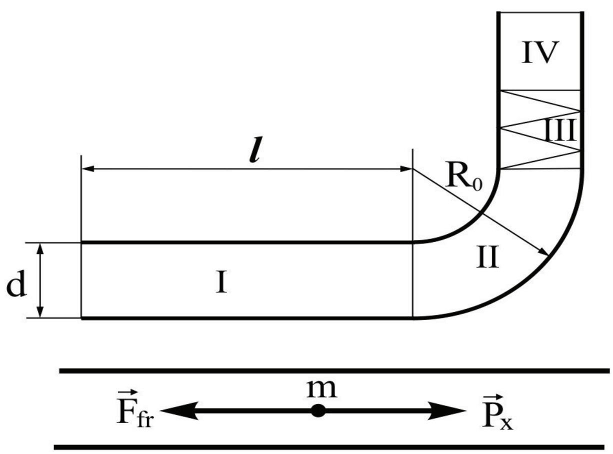


Fig. 4. Sections of the material supply tube

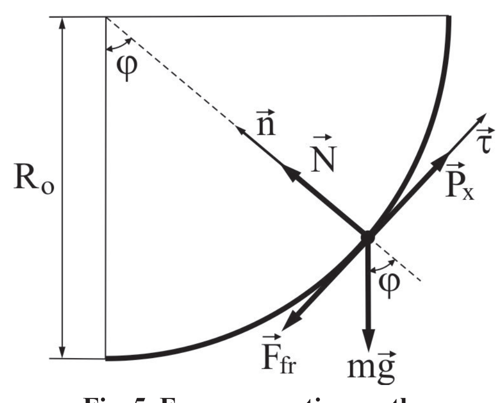


Fig. 5. Forces operating on the fertilizer particle in section II

In this case the equation (18) will become:

$$u\frac{du}{d\phi} = f \cdot u^2 + R_0 \cdot f \cdot g \cdot \cos\varphi + R_0 \cdot g \cdot \sin\ \varphi \qquad (19)$$

Integrating (19) under initial conditions $u = u_1$ and $\varphi = 0$ we will receive expression for definition of velocity of a particle:

$$\frac{\left\{\left[\left(e^{2f\cdot\varphi}-1\right)+\left(1-e^{2f\cdot\varphi}\right)2f^2\right]\cos\varphi - 3f\cdot e^{2f\cdot\varphi}\cdot\sin\ \varphi\right\}2g\cdot R_0+(1+4f^2)u_1^2}{(1+4f^2)e^{2f\cdot\varphi}} = u^2 \qquad (20)$$

where u_1 is calculated from expression (15).

Obviously, the particle velocity u_2 - on the output from the bow section II to the vertical section III is to be found, where $\varphi = \pi/2$. Thus (20) looks like:

$$u_2^2 = \frac{(1+4f^2)u_1^2 - 6f \cdot g \cdot R_0 \cdot e^{\pi \cdot f}}{(1+4f^2)e^{\pi \cdot f}} \qquad (21)$$

On the section III the screw is installed, which whirls the two-component stream. Operations of forces on a particle *M* of mineral fertilizer can be presented schematically, as in Figure 6. Here the normal reaction N_1 is counterbalanced by a centrifugal force $\frac{m \cdot u^2}{R}$. Normal reaction of basic surface N is directed on a binormal and counterbalanced by the force of gravity $m \cdot g$. Aerodynamic motive force P_x is counterbalanced by force of friction *F*.

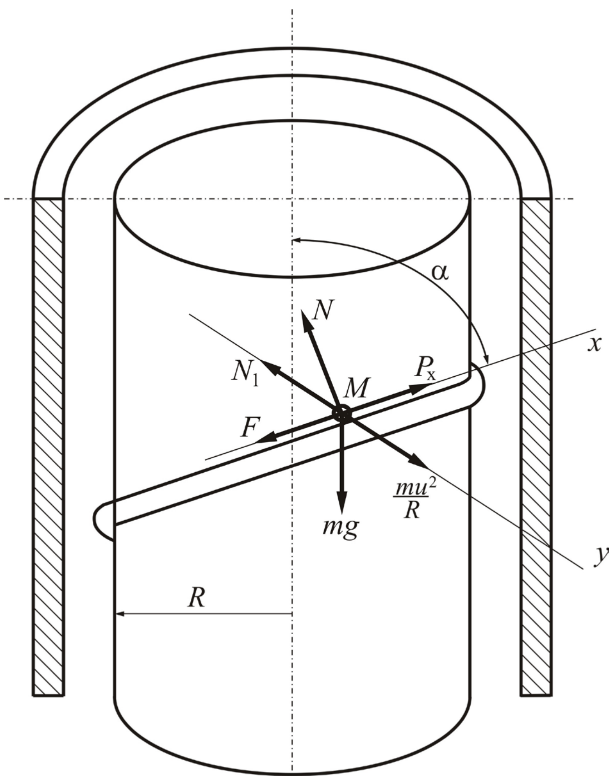


Fig. 6. Forces operating on the fertilizer particle in section III

The set of equations, particles characterising particles movement on natural axes *x, y, z* will be noted as follows:

$$\begin{aligned} &m \cdot \ddot{x} = P_x - F - m \cdot g \cdot \cos\alpha = 0; \\ &m \cdot \ddot{y} = \frac{m \cdot u^2}{R} - N_1 = 0; \\ &m \cdot \ddot{z} = N - m \cdot g \cdot \sin\alpha = 0. \end{aligned} \qquad (22)$$

From system (22) define *N*, N_1, *F* and with the account:

$$P_x = m\frac{du}{dt} \quad ,$$

rewrite the first equation in (22):

$$\frac{du}{dt} = f\left(g \cdot \sin\alpha + \frac{u^2}{R}\right) + g \cdot \cos\ \alpha \qquad (23)$$

It also is a differential equation of movement of a fertilizer particle on the wind surface under the influence of aerodynamic moving force.

Transform the equation (23) accepting designations:

$$g(f \cdot \sin\alpha + \cos\alpha) = A\,; \ \frac{f}{R} = B \qquad (24)$$

Thus equation (23) becomes:

$$\frac{du}{A + B \cdot u^2} = dt \quad . \qquad (25)$$

Differential equation from the divided variable is derived, which solution looks like:

$$\frac{1}{\sqrt{A \cdot B}} \arctan u\sqrt{\frac{B}{A}} + C = t \cdot \qquad (26)$$

At $t = 0$, $u = u_2$

$$C = \frac{1}{\sqrt{A \cdot B}} \arctan u_2\sqrt{\frac{B}{A}} \quad .$$

Value *C* is substituted in (26):

$$\arctan u_3\sqrt{\frac{B}{A}} = \sqrt{A \cdot B} \cdot t - \arctan u_2\sqrt{\frac{B}{A}} \qquad (27)$$

Equation (27) connects such parametres of a twisting wind surface as its radius and a circular helix angle of wind with which help it is possible to calculate its lead and length.

Discussion

To verify the calculated results, the particle velocity is calculated at each stage of its passage through pneumopipeline. This requires parameters, some of which can be taken from the literature and some are established in preliminary laboratory experiments:

υ_S = 5 m·s^{-1} – initial velocity of the particle in a pneumostream;

υ = 20 m·s^{-1} – working velocity of the air stream;

f = 0.5 – coefficient of external friction of the fertilizer;

d = 0.1 m – internal diameter of the pipeline;

R_0 = 0.5 m – radius of the bow section;

α = 60° - circular helix angle of wind.

Having substituted the accepted parameters in the equation (15)

$$u_1=\frac{20\left(e^{\frac{2\cdot 9.81\cdot 1}{5}}-\dfrac{1-0.25}{1+0.25}\right)-5\left(e^{\frac{2\cdot 9.81\cdot 1}{5}}+\dfrac{1-0.25}{1+0.25}\right)}{e^{\frac{2\cdot 9.81\cdot 1}{5}}-\dfrac{1-0.25}{1+0.25}}=14.87\ \text{m·s}^{-1}$$

have received a particle velocity on the section I.

Value of this velocity is necessary to know to define time for which fertilizer particles reach maximum velocity, and consequently, certain stable distribution on the material supply tube's cross-section. From (15) and Figure 7 it follows that time of particles acceleration varies within 1 – 1.4 sec.

Equation (21) gives a particle velocity on an exit from a vertical tap (exit of section II):

$$u_2^2=\frac{(1+4\cdot 0.5^2)\cdot 14.87^2-6\cdot 0.5\cdot 9.81\cdot 0.5\cdot e^{3.14\cdot 0.5}}{(1+4\cdot 0.5^2)e^{3.14\cdot 0.5}}=38.71$$

$u_2 = 6.22$ m·s^{-1}.

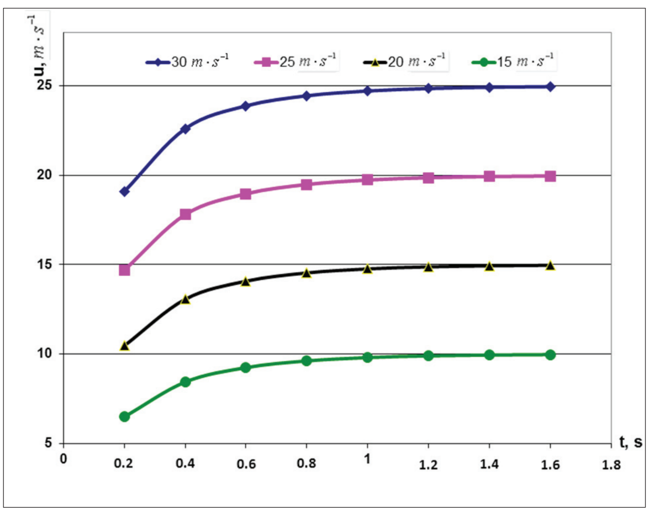


Fig. 7. Dependence of a particle movement velocity on time

It is apparent from last evaluation, that at the 90^0 turn (bow section), the particle loses the velocity, for more than two times.

From the analysis of equation (21) and Figure 8 it is visible that with reduction of radius R_0 of bow section, the particle velocity u_2 decreases.

To calculate a particle velocity on the twisting wind surface, the equation (27) is used. For this purpose beforehand factors A and B are calculated using formula (24):

$$\arctan u_3\sqrt{\frac{1}{9.15}}=\sqrt{9.15\cdot 1}-\arctan 6.22\sqrt{\frac{1}{9.15}}=1.921;$$

$u_3 = 5.82$ m·s^{-1}.

Considering vertical section IV (Figure 9).

In (11) r is density of load-carrier. It is equal to weight of its individual volume ($m\cdot q/1\text{m}^3$). In this case having introduced designation $\frac{1}{2}k_x\cdot A_r\cdot q=a$, the equation will come to the form:

$$\frac{du}{dt}=a(\upsilon-u)^2-g. \tag{28}$$

A differential equation with divided variables is received. Then it is transformed in:

$$\frac{du}{a(\upsilon-u)^2-g}=dt. \tag{29}$$

Equation (29) is table mode. Its solution looks like:

$$\frac{1}{2\sqrt{a\cdot g}}\ln\frac{\sqrt{g}+(\upsilon-u)\sqrt{a}}{\sqrt{g}-(\upsilon-u)\sqrt{a}}=t+C \tag{30}$$

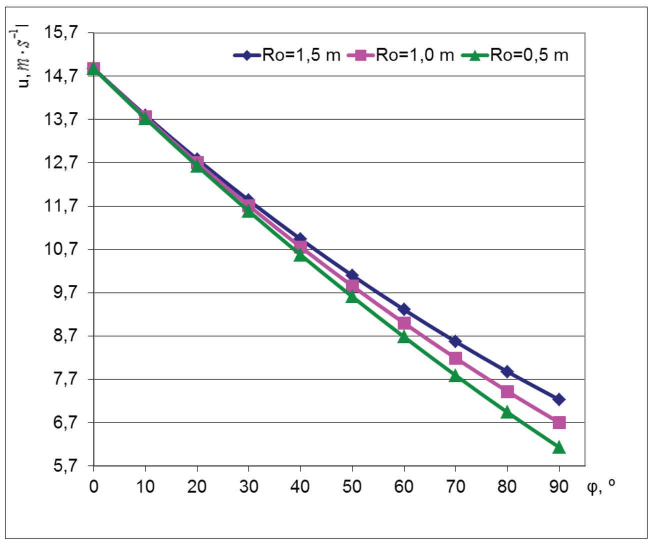


Fig. 8. Dependence of particle velocity on an angle of rotation

At $t = 0,\ \ u = u_3$ from (30) it is received:

$$C = \frac{1}{2\sqrt{a \cdot g}} \ln \frac{\sqrt{g} + (\upsilon - u_3)\sqrt{a}}{\sqrt{g} - (\upsilon - u_3)\sqrt{a}}\ .$$

Substituting the received expression in (30):

$$\frac{\left[\sqrt{g} + (\upsilon - u_4)\sqrt{a}\right] \cdot \left[\sqrt{g} - (\upsilon - u_3)\sqrt{a}\right]}{\left[\sqrt{g} - (\upsilon - u_4)\sqrt{a}\right] \cdot \left[\sqrt{g} + (\upsilon - u_3)\sqrt{a}\right]} = e^{2t\sqrt{a \cdot g}} \quad (31)$$

Calculate the velocity of a particle value in the vertical pipeline with the equation (31). For a turbulent condition, at $R = 0.5$ m, accept factor $k_x = 0.43$ and $A_r = \pi \cdot R^2$. In this case the factor a is equal:

$$a = 0.5 \cdot 0.43 \cdot 3.14 \cdot 0.0025 \cdot 9.81 = 0.15\,.$$

Taking into account losses on I, II and III sections, air velocity is taken equal to 10 m·s^{-1}, and the particle in section IV arrives with a velocity of 5.82 m·s^{-1}.

Substitute values of the constitutes in the equation (30):

$$\frac{\left[\sqrt{9.81} + (10 - u)\sqrt{0.15}\right] \cdot \left[\sqrt{9.81} - (10 - 5.82)\sqrt{0.15}\right]}{\left[\sqrt{9.81} - (10 - u)\sqrt{0.15}\right] \cdot \left[\sqrt{9.81} + (10 - 5.82)\sqrt{0.15}\right]} = e^{2t\sqrt{a \cdot g}}$$

As a result of calculations it is found that u_4=2.55 m·s^{-1}. Hence, the particle velocity in the vertical pipeline will decrease to this velocity.

Knowing the necessary velocity of particles at the outflow, satisfying transportation and uniform distribution on taps, by means of velocity and time in a way it is possible to calculate possible height of the vertical pipeline.

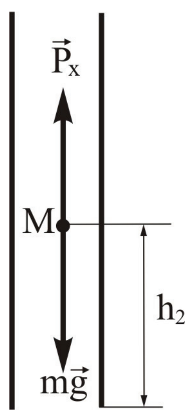


Fig. 9. Forces operating on the fertilizer particle in section IV

Conclusion

The offered mode of turn of a transport line ensures the stable distribution law of particles of mineral fertilizers in a cross-section of material supply tube on an input in the working organ, concentrated on the exterior side of the turn (bow) section. Installation of a whirler on a way of the stabilised stream, made in a form of quadruple helical spiral with linear shift of the beginning of winds, transfers the first a rotation which promotes distribution of particles by an equal stratum on an internal wall of the material supply tube. Theoretical substantiations of displacement of the beginning of winds, velocities of particles in four sections – horizontal, bow, with a whirler and in vertical (before a dividing head), allow to fulfil calculations of their design parameters.

References

Asmolov, E. S., 1995. Dusty-gas flow in a laminar boundary layer over a blunt body. *J. Fluid Mech*., **305**: 29-46.

Ben Salem, M. and B. Oesterle, 1998. A shear flow around a spinning sphere: numerical study at moderate Reynolds numbers. *Int. J. Multiphase Flow*. **24**(4): 563-585.

Bird, G. A., 1994. Molecular Gas Dynamics and the Direct Simulation of Gas Flows. *Clarendon Press*, Oxford, 458 pp.

Cakmak, B., E. Aykas, I. Onal and E. Cakir. 2010. The performance of developed rotary tiller fitted with pneumatic seeder. *Bulgarian Journal of Agricultural Science*, **16** (6): 801-810.

Crowe, C. T., T. R. Troutt, J. N. Chung, R. W. Davis and E. F. Moore, 1995. A turbulent flow without particle mixing. *Aerosol Sci. and Technology*. **22**: 135-138.

Crowe, C. T., T. R. Troutt and J. N. Chung, 1996. Numerical models for two-phase turbulent flows. *Annu. Rev. Fluid Mech*, **28**: 11-43.

Crowe, C. T., M. Sommerfeld and Tsuji Yu, 1998. Multiphase flows with droplets and particles. *CRC Press*, 471 p.

Kurose, R. and S. Komori, 1999. Drag and lift forces on a rotating sphere in a linear shear flow. *J. Fluid Mech*.

Nefyodov, B. A., 1991. Mechanical-technological basics of development of intrasoil fertilizer application machines. *The collection of proceedings*, Moscow, WIM, 126:16 (Ru).

Nukeshev, S. O., 2009. Technical solution to the problem of uniform distribution of particulate material. *Journal of Science of Z. Aldamzhar Kostanay socio-technical university - Kostanay* (ITC KSTU), **10**(1): pp.141-146. (Ru)

Oesterle, B. and T. Bui Dinh, 1998. Experiments on the lift of a spinning sphere in a range of intermediate Reynolds numbers. *Experiments in Fluids*, **25**: 16-22.

Osiptsov, A. N., 1997. Mathematical modeling of dusty-gas boundary layers. *Appl. Mech. Rev*., **50 (**No.6): 357–370. (ASME Reprint No.• AMR 214.)

Osiptsov, A. N., 2000. Lagrangian modelling of dust admixture in gas flows. *Astrophysics and Space Science*, **274**: 377-386.

Osiptsov, A. N., L. A. Egorova, V. I. Sakharov and B. Wang, 2002. Heat transfer in supersonic dusty-gas flow past a blunt body with inertial particle deposition effect. *Progress in Natural Science*, **12**(12): 887-892.

Patent 19007 RK, 2008. Device for the distribution of bulk material / Nukeshev S.O., Nurgaliyev T.K. et al., publ. 15.01.2008, Bull. Number 1. - 4 p.: Il. (Ru)

Schumann, A. W., 2010. Precise placement and variable rate fertilizer application technologies for horticultural crops. *Hort Technology,* **20**(1): 34-40.

Schumann, A. W. and K. H. Hostler. 2010. Variable rate application technology for enhanced production efficiency. Instituto Agronmico do Paran, Londrina, Parana, Barzil.

Sommerfeld, M., 1993. Application of optical non-intrusive measurement techniques for studies of gas-solid flows. *Gas-solid flows. FED* (ASME. New York), **166**: 193-213.

Sommerfeld, M., 1993. Review on numerical modeling of dispersed two-phase flows. In: *Proc. 5th Int. Symp. on Refined flow modeling and turbulence measurements*. Paris, Sept. 1993, pp. 1-16.

Sommerfeld, M., N. Huber and P. Wachter, 1993. Particle-wall collisions: experimental studies and numerical models. *Gas-solid flows. FED* (ASME. New York), **166**: 183-191.

Tsirkunov, Yu. M. and S. V. Panfilov, 1994. Dusty gas flow around bodies: effects of non-elastic reflection of particles. In: *2nd European Fluid Mechanics Conference*. (Abstracts of Papers, September 20-24, 1994. Warsaw, Polland) Warsaw, p. 274.

Tsirkunov, Yu., N. Tarasova and A. Volkov, 1994. Boundary layer effects in the dusty gas flow over a blunt body. *Proc. Estonian Acad. Sci. Phys. Math*. **43**(4): 250-262.

Zuev, F. G., 1976. Pneumatic transportation on grain processing enterprises. *Kolos*,Moscow, 344 pp. (Ru)

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