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MODELLING OF MOVEMENT OF PARTICLES OF VARIOUS WEIGHTS IN THE DIVISION CHAMBER

Process of clearing and fractionating of grains is considered. The new device containing the distributor and the chamber of separation is developed. Movement of the particles of the grain mixture taking off the distributor for the purpose of substantiation of parameters of the device, by criterion fractionating of the particles of the grain mixture on the weight is investigated. The equation of movement of any particle of the grain mixture is worked out and mathematical expressions for definition of the distance from the beginning of co-ordinates to the point when any particle of the grain mixture will rise on the maximum height are deduced. It is established, that the height of lifting of the grain changes in direct ratio initial speed, weight and in inverse proportion to the factor of resistance of air. The received expressions allow to investigate and define parameters of separator of division of particles on weight depending on initial speed, a corner of a start and factor of resistance of air.
Key words: *clearing, fractionating, weight, the equation of movement, resistance of air.*

One of the factors for reception of flour of high quality and other bread-baking products is clearing of grain of impurity and its uniformity, i.e. presence of considerable quantity of the grains close on its size.

Nowadays, there are more than100 grades and kinds of grain crops in our agriculture. For each grade of grain, there is a physical and chemical structure and mechanical characteristics. Despite it, they are given at the same time to the technological processing and in one operating mode in rolling machine tools. Its versatile of the wheat grains leads to release of a poor-quality flour, bread other and bread-baking products. Wear out of shafts increases in such process of work. It is necessary to notice, that effective usage of the grain on mills is defined not only by the level of the technology, which was accepted at these enterprises, but also by the physical and chemical, mechanical and technological properties of the grain, which are formed under the influence of genetic and geometrical parameters.

One of perspective directions of perfection of process of grain preparation to grinding is an introduction of fractional separating of the grain for division clearing, water-thermal processing and grinding of its fractions.

The process of separating of the grain, while preparing it for a grinding at flour-grinding factories, is considered as totality of 3 processes:

- Clearing of the grain - extraction of weed and grain impurity from a grain mix in the form of separate fractions;

- Fractionating of the grain mixture - its divisions into the fractions, differing structure of impurity and physic mechanical properties of the basic component - grains;

- Sorting of the grain - divisions of the cleared grain into the fractions, differing aerodynamic and physic mechanical properties.

In traditional technology of clearing of loose materials, the processed mixture is consistently cleared from various impurity by the admission through a certain complex of cleaners, in which the principle of division of the mixture in air stream is used, i.e., the basic working bodies are the pneumatic separators vibrating and conveyor sieve [1, 2, 3].

Well known machines do not provide sufficient clearing and grain divisions on fractions. Perfection of the process of clearing and fractionating of the grain [1, 4] is on perspective.

For the purpose of combination of process of clearing and fractionating grains we have worked out the new device containing the distributor 1, on width of the chamber of separation, the chamber of separation, which is divided on length by moving partitions and compartments. Where the distributor is executed in the form of the feeding platen 2, with the brushes, which are located on the surface of brushes or brush blades 3 under which with the possibility of regulation of the corner of inclination the directing tray 4 is established. Thus, each compartment is divided into two, and in one of compartments the inclined sieve and trays are established and the other is located with the possibility of interaction with a tray (fig. 1) [5].

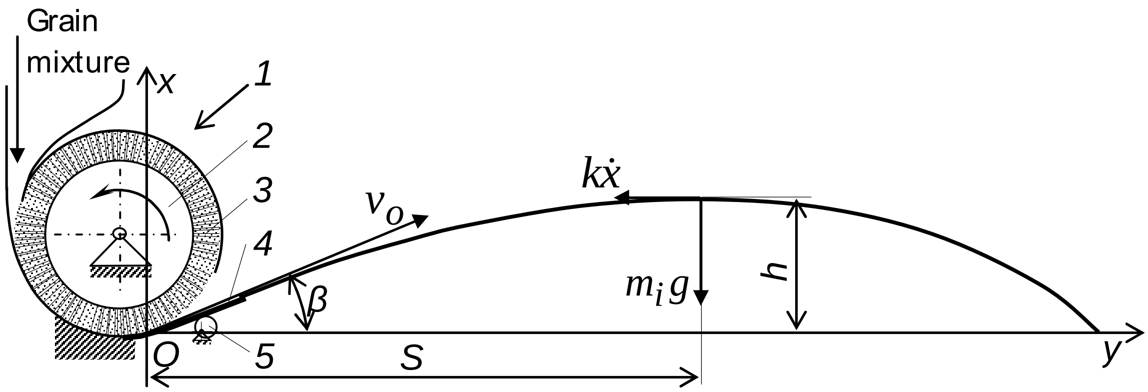

Fig. 1. The Scheme of the flight of the grain mixture in the separation chamber

The initial grain mixture, from a feeder, arrives in a zone of the distributor which is executed in the form of the feeding roller with the brushes established on a cylindrical surface or brush blades. The grain mixture, gathering appropriate speed, from the rotary movement of the feeding roller go into the directing tray, which corner of inclination is regulated in limits from 0 to 45^o and are established depending on the speed of take off initial mixture and length of the chamber of separation. Grains of an initial mixture, flying by on a certain trajectory, appropriate to their weight are divided on all the length of the chamber of separation into fractions and enter into appropriate compartments.

Grains with more greater weight, i.e. seed grains or other possible impurity, fly by a large distance and enter into the most distant compartment. The grains that have hardly less weights, i.e. food grains or other possible impurity, than seed, fly by accordingly to their weight hardly less distance and enter into a corresponding compartment. Thus, the grain mixture, depending on the weight is divided on all length of the chamber separation into fractions and enter into appropriate compartments.

For a substantiation of parameters of that device by the criterion of fractionating of the grains or particles of impurity on weight, we investigate movement of grains or impurity particles, further particles of the grain mixture taking off distributor, i.e., brushes or brushed blades of the feeding platen.

Let's designate the weight of the particles, containing in the grain mixture through $m_i, (i = 1..., n)$. All the particles, while taking off from the distributor will have the identical initial speed v_0, which vector is directed to axis OX under corner β. The special mechanism of regulation of the corner of the inclination 5, directing tray allows to establish it on the demanded size. At flight on the movement the power of the gravity of the particles is operated $m_i g$, where: m_i-weight i - particles, g-acceleration of free falling and the resistance of the air is proportional to the first degree of the speed $k\dot{x}$ [1]. Here $\dot{x}$ is the - speed of the flight of the particle, k is the factor of the resistance of the air. It is difficult precisely to define the value of the factor of resistance of air k. As it depends on a great number of casually, changing aerodynamic properties and factors as speeds of the movement, the relative density, the volume, the form and roughness's of the surface of the particle, impurity and properties of the air environment of the chamber of the separation, nevertheless, there are some researches have being done dealing its definition [1, 4].

Let's work out the equations of movement $i-$ of the particle on axis Ox and Oy:

$$\begin{cases} m_i \ddot{x} = -k\dot{x}, \\ m_i \ddot{y} = -m_i g - k\dot{y}. \end{cases} \quad (1)$$

Considering, that in the second equation of the system (1) $\ddot{y} = \frac{d\dot{y}}{dy}\dot{y}$, we have

$$\dot{y} \cdot d\dot{y} \Big/ \dot{y} + \frac{m_i \cdot g}{k} = -\frac{k}{m_i} dy \quad . \quad (2)$$

After some transformations (2) we will receive,

$$(\dot{y} + \frac{m_i \cdot g}{k} - \frac{m_i \cdot g}{k}) \cdot d\dot{y} \Big/ \dot{y} + \frac{m_i \cdot g}{k} = -\frac{k}{m_i} \cdot dy,$$

or

$$d\dot{y} - \frac{m_i \cdot g}{k} d\dot{y} \Big/ \dot{y} + \frac{m_i \cdot g}{k} = -\frac{k}{m_i} dy \quad . \quad (3)$$

Integrating (3), we will receive

$$\dot{y} - \frac{m_i \cdot g}{k} \cdot \ln(\dot{y} + \frac{m_i \cdot g}{k}) = -\frac{k}{m_i} y + c, \quad (4)$$

Where c is arbitrary constant. At $y = 0$ and $t = 0$ $\dot{y} = \upsilon_0 \sin\beta.$ Taking into account these terms from (4) we'll find C,

$$C = v_0 \cdot Sin\beta - \frac{m_i \cdot g}{k} \ln(v_0 \cdot Sin\beta + \frac{m_i \cdot g}{k}) .$$

In the result ordinate for the particle of the weight $m_i, (i = 1, n)$, it is possible to define under the formula

$$Y = \frac{m_i}{k} \cdot (v_0 \cdot Sin\beta - \dot{y}) + \frac{m_i^2 \cdot g}{k^2} \cdot \ln(\dot{y} + \frac{m_i \cdot g}{k} \Big/ v_0 \cdot Sin\beta + \frac{m_i \cdot g}{k}) . \quad (5)$$

Supposing in the formula (5) extreme values $\dot{y}=0$ and $y=h$ we will find the maximum height on which the weight of the particle m_i $(i=1,\ n)$ will rise.

$$h=\frac{m_i}{k}\cdot v_0\cdot Sin\beta-\frac{m_i^2\cdot g}{k^2}\cdot \ln\left(\frac{V_0\cdot Sin\beta+\frac{m_i\cdot g}{k}}{\frac{m_i\cdot g}{k}}\right). \tag{6}$$

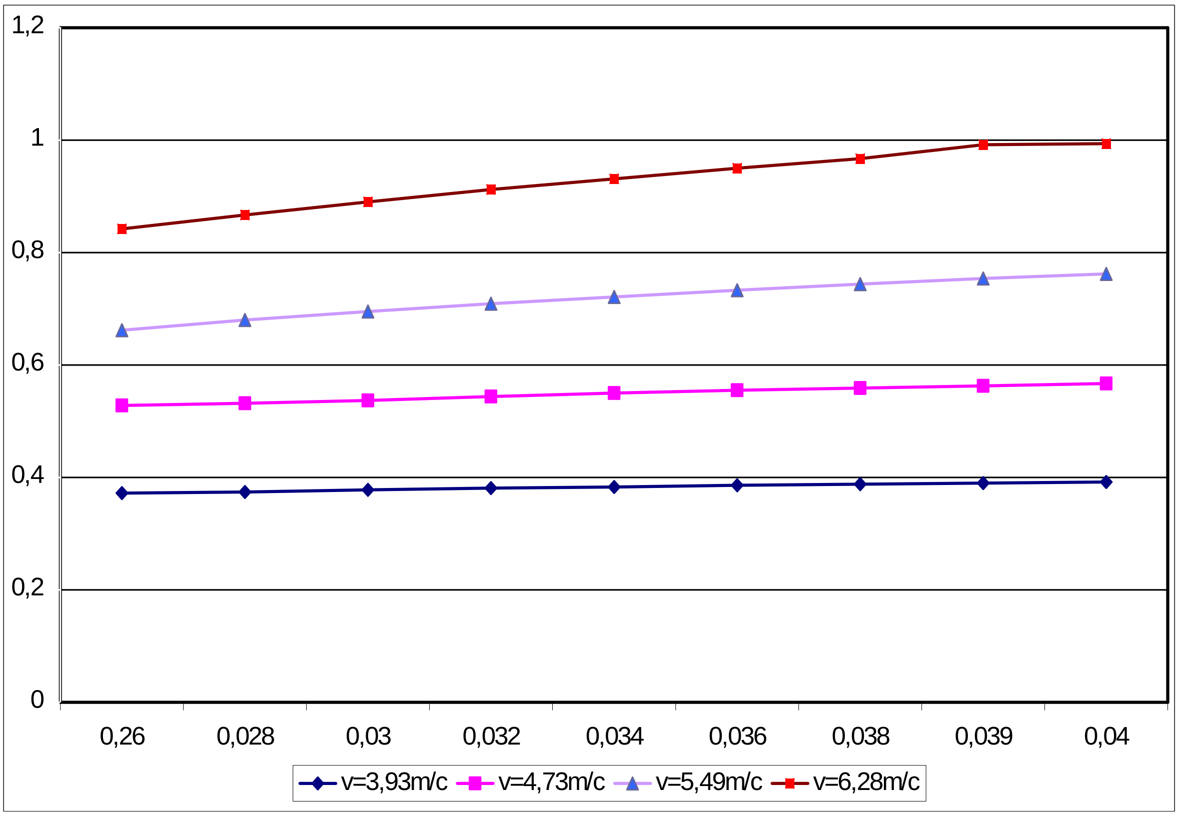

Fig. 2. The schedule of the dependence of the height of the lifting of the grain mixture from the speed of the air

It is established, that the height of the lifting of the grain changes in direct ratio initial speed, weight and in inverse proportion to factor of the resistance of the air. In pic. 2 the schedule of the change of the height of the lifting of the grain mixture depending on the weight of the grain mixture is resulted at initial speed of the grain mixture $v_0=3{,}93;\ 4{,}73;\ 5{,}49;\ 6{,}28$ м/с and corner of lifting $\beta=45^{\circ}$.

Let's work out now the equation of the movement of arbitrary particle of the weight m_i ($i = 1 \ldots, n$) in a projection to an axis *OX*,

$$m_i\ddot{x}=-k\dot{x} \quad \text{or} \quad \ddot{x}=-\frac{k}{m_i}\dot{x}. \tag{7}$$

In (7) we will designate $Z(t)=\dot{x}(t)$. In the result we will have

$$\dot{z} = -\frac{k}{m_i} z \ . \tag{8}$$

After integration (8) we will receive $\ln z = -\frac{kt}{m_i} + \ln c_1$. Whence it follows

$$z = c_1 \cdot e^{-\frac{k \cdot t}{m}} \qquad \text{or} \qquad \dot{x}(t) = c_1 \cdot e^{-\frac{kt}{m_i}} \ . \tag{9}$$

At t=0; x=0; $\dot{x} = V_0 \cos\beta$. On the basis of it from (9) we will receive $c_1 = v_0 \cos\beta$. Substituting significance c_1 in (9) we will copy it in a kind of,

$$\dot{x}(t) = V_0 \cdot \cos\ \beta \cdot e^{-\frac{kt}{m_i}} \ . \tag{10}$$

After integration (10) we will find

$$x(t) = -\frac{m_i \cdot V_0 \cdot \cos\beta}{k} e^{-\frac{kt}{m_i}} + c_2 \ . \tag{11}$$

Using the term $x(t)\big|_{t=0} = 0$ we will define $c_2 = \frac{m_i}{k} \cdot V_0 \cdot \cos\beta$ In the result after substitution c_2 in (10) we will find,

$$x(t) = \frac{m_i}{k} \cdot V_0 \cdot \cos\beta(1 - e^{-\frac{kt}{m_i}}) \ , \tag{12}$$

we will return to the equation (1) again

$$\frac{d^2 y}{dt^2} = -\frac{k}{m_i} \cdot (\frac{dy}{dt} + \frac{m_i \cdot g}{k}) \ . \tag{13}$$

Let's designate $u(t) = \frac{dy}{dt}$. Then (13) it will be rewritten as following, $\frac{du}{dt} = -\frac{k}{m_i}(u + \frac{m_i g}{k})$. Dividing variables we will receive $du \Big/ u + \frac{m_i \cdot g}{k} = -\frac{k}{m_i} dt$. The integral of this parity looks like $\ln(u + \frac{m_i g}{k}) = -\frac{k}{m_i} t + \ln c_3$. After potentiating we will write down $u + \frac{m_i g}{k} = c_3 e^{-\frac{k}{m_i} t}$. Or on the basis of communication $u(t) = \frac{dy}{dt}$ we will have ,

$$\frac{dy}{dt} + \frac{m_i g}{k} = c_3 \cdot e^{-\frac{k}{m_i} t} \ . \tag{14}$$

Using the entry term $\frac{dy}{dt}\Big|_{t=0} = V_0 Sin\beta$ we are defining constant $c_3 = V_0 \cdot Sin\beta + \frac{m \cdot_i g}{k}$. Substituting which in (14) we will find

$$\frac{dy}{dt} + \frac{m_i \cdot g}{k} = (V_0 \cdot Sin\beta + \frac{m_i \cdot g}{k})e^{-\frac{k}{m_i}t}.$$

If $\frac{dy}{dt}$ will address in a zero, than

$$e^{-\frac{k}{m_i}t} = \frac{m_i \cdot g}{k} \Big/ V_0 \cdot Sin\beta + \frac{m_i \cdot g}{k}. \qquad (15)$$

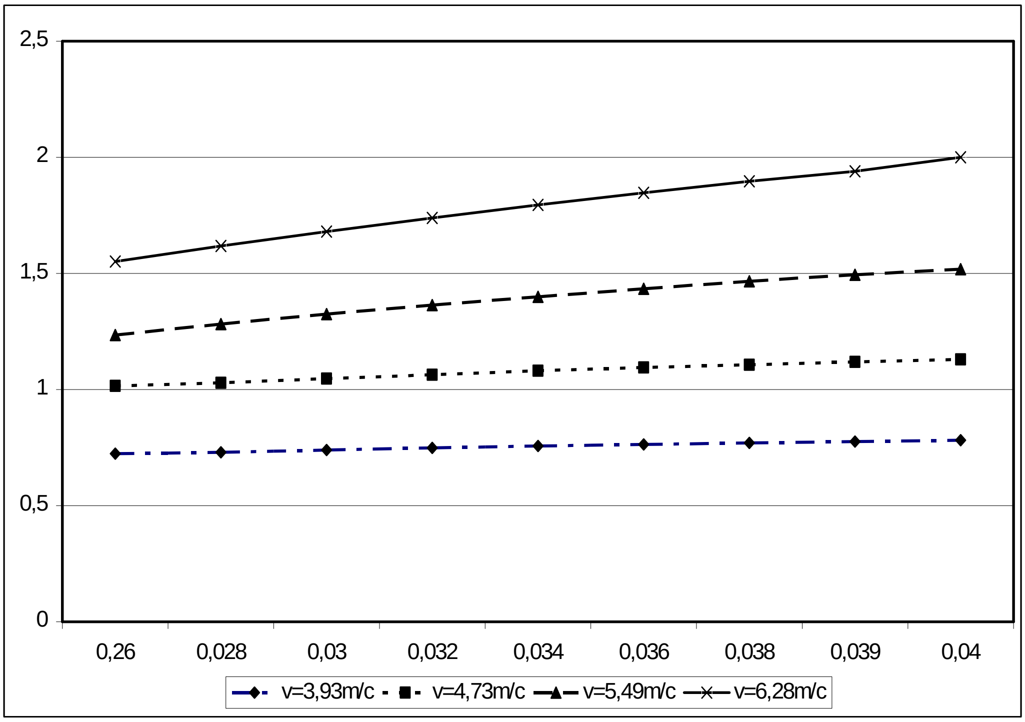

Fig. 3. The schedule of the dependence of distance of the grain mixture from the beginning of coordinates to a point when the particle of weight m_i will rise on the maximum height h depending on weight and speed of the grain

In the result on the basis (15 from (12) we can find the distance from the beginning of co-ordinates to a point when the particle of weight m_i will rise on the maximum height h,

$$s = \frac{m_i}{k} V_0 \cdot cos(1 - \frac{\frac{m_i \cdot g}{k}}{V_0 \cdot Sin\beta + \frac{m_i \cdot g}{k}}) = \frac{m_i \cdot V_0 \cdot cos\beta}{k} \cdot \frac{V_0 \cdot Sin\beta}{V_0 \cdot Sin\beta + \frac{m_i \cdot g}{k}}.$$

Thus, we will definitely write down,

$$s = V_0^2 \cdot Sin2\beta \Big/ \frac{2k}{m_i}(V_0 \cdot Sin\beta + \frac{m_i \cdot g}{k}) . \quad (16)$$

The received expressions allow to investigate and define parameters of the device of division of particles on weight depending on initial speed, a corner of a start and factor of resistance of air.

From the schedule (pic. 2 and 3) it is visible, that with increase in speed the height of lifting of particles of the grain mixture grows. Also from the schedule it is visible, that the height of lifting of particles of the grain mix increases proportionally to increase in weight of particles of the grain mixture. Accordingly the particles that have greatest weight rise on the greatest height and fly by on the maximum distance on OH. Thus, the grain mixture (seed, food, fodder grains, seeds of other plants and different possible impurity) depending on weight are divided on all length of the chamber of separation on fraction and are included into corresponding compartments where special adaptations provide division of grains from every possible other impurity (seeds of others, a plant, stones etc.). The dust and easy particles (straw and other impurity) leave from the separation chamber by the aspiration.

In expression (16) parameters are defined which will be used at a choice of operating modes of a separator.

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