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THE DYNAMICS OF PARTICLES MOVEMENT IN THE INDENTED CYLINDER

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Abstract: *The mixtures which compose the mass of seeds have different characteristics, this thing leading to a non homogenous mass of seeds, from the point of view of quality. By this reason, for the sorting in good conditions of the mass of seeds, it must be analyzed the physical-mechanical characteristics of seeds and impurities which compose the mass to be separated, in order to establish the technology of separation of impurities. The main characteristics which decide the sorting methods of seeds are: dimensions of seeds and impurities, shapes, state of surfaces, mechanical strength, elasticity, specific weight, electric properties, colors of seeds and impurities. The technological and commercial value of the mass of seeds is diminished by the non uniformity as size, shape and color of seeds. The sorting of the mass of seeds is made in order to increase the purity and realizing of homogenous masses of seeds from the point of view of the seed uniformity. As a function of separation simplify by mechanical methods, the impurities are classified as easily and difficultly separable. The separation of seeds in fractions, as a function of dimensions (length, thickness, width), comprised between some limits, is called calibration. The indented cylinder is used for sorting by length all cereals seeds such as wheat, oats, barley, sunflower, sugar beet seeds, alfalfa and for separating unwanted long or short product impurities. In order to calculate and design the sorting machines, it is necessary to establish the laws of motion of the seeds in the indented cylinders. The study of the seed movement in the indented cylinder was realized using the dynamic model of material particle. The process of separation of seeds with the indented cylinder, respectively the efficiency of seed separation, is influenced by the cylinder construction (diameter, dimensions of pockets), cylinder inclination, speed of rotation and by the character of the relative motion of seeds in the indented cylinder, respectively by the kinematical index of cylinder. The design and construction of the seed sorting machines is influenced by the structure and physical-mechanical properties of seeds.*

Key words**:** *indented cylinder, particle, relative motion, force, kinematical index.*

INTRODUCTION

The grain and seed products that are stored in silos come in most cases directly from harvesting and contain, in addition to the basic product, in the mixture, different foreign components consisting of: mineral impurities, organic residues, weeds seeds, seeds of other cereals, broken grains and so on. The presence of these components in the grain mass of the basic product exerts a negative influence on the storage of the products, diminished the technological and commercial value of the mass of seeds.

Conditioning is the technological process by which the seeds are brought to the requirements imposed by cleaning, sorting, calibration and drying operations. To improve the purity of the products and to make homogeneous batches in terms of seed uniformity, the mass product is cleaned and sorted.

MATERIAL AND METODS

The indented cylinder sorts masses of seeds by length and roundness. The most important part of the separator is the cylinder shell, a rotating cylinder made of metal sheet (Figure 1). The cover of the cylinder shell is provided with pockets or so-called indents.

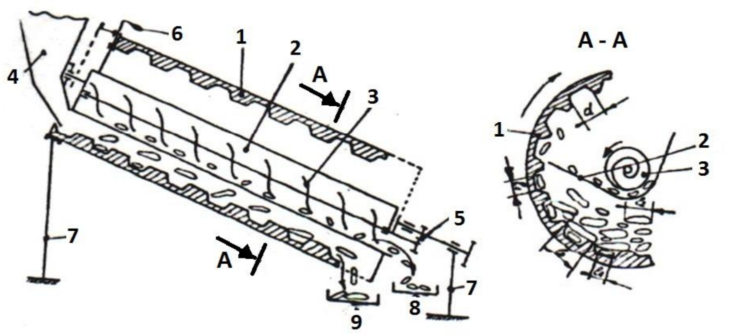

Figure 1: Sorting seeds by length
1-cylinder shell, 2-trough, 3-screw conveyor, 4-inlet housing, 5-trough adjustment, 6-trough adjustable inclination, 7-framework, 8-outlet casing short grain, 9-outlet casing long grain.

The mass of seeds passes from the inlet housing into the interior of the rotating cylinder shell. The grains that embed themselves in the indents, will be carried and after a certain distance, will fall out of the pockets into the trough, and will be discharged by a screw conveyor. All grains which are larger than the indents, will remain inside the shell and be carried to the outlet where the shell empties into the outlet casing. Depending on the required grading the incoming product will be sorted according to roundness or length.

The operation of separation of seeds is analyzed with the help of the particle model (Figure 2). The particle of mass m behaves inside the indented cylinder as a mathematical pendulum. The study of the movement is done with the Frenet frame, in the $O\xi\eta$ mobile axle system. The selected axle system rotates in the same time with the cylinder shell. The angular speed is ω and the cylinder radius is r.

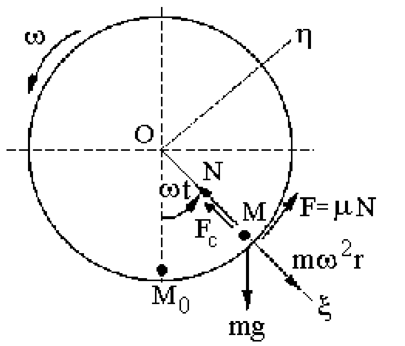

Figure 2: Dynamic model

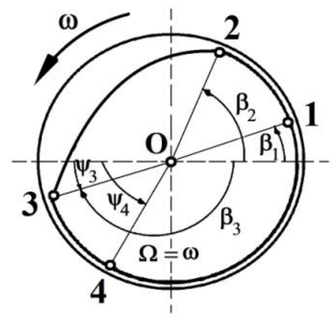

Figure 3: Motion regimes

It is supposed that at some initial moment ($t = t_0$), the particle is at the lowest point (M_0) of the surface. It is analyzed under what conditions this particle is in relative rest if the cylinder, will rotate after some time with the angle $\theta = \omega \cdot t$. When there is no sliding motion, the particle together with the cylinder will also rotate with the angle $\theta = \omega \cdot t$ and move from the position M_0 to the position represented by the point M.

The forces which act on the particle are:

- weight force $G = m \cdot g$;
- Normal force N;
- Friction force $F_f = \mu \cdot N$
- Centrifugal force $F_{cf} = m \cdot \omega^2 \cdot r$.

The orientation of these forces which act on the material particle was presented in Figure 2.

The differential equations of the material particle motion have the form:

$$m \cdot \omega^2 \cdot r - N + m \cdot g \cdot \cos \omega t = 0; \qquad (1)$$
$$\mu \cdot N - m \cdot g \cdot \sin \omega t = 0.$$

From the first equation we determine the normal reaction N:

$$N = m\left(\omega^2 r + g \cos \omega t\right) = mg\left(\frac{\omega^2 r}{g} + \cos \omega t\right). \qquad (2)$$

Where:

$$k = \frac{\omega^2 r}{g}, \qquad (3)$$

Ratio between centrifugal acceleration and gravitational acceleration is the kinematical index of indented cylinder.

Therefore the normal reaction becomes:

$$N = mg\left(k + \cos \omega t\right). \qquad (4)$$

Unlike the mathematical pendulum where the link is ideal, within the indented cylinder the link is not ideal, and the movement is transmitted to the particle by friction. Due to the frictional force characteristics, particle motion on the inner surface of the indented cylinder is more complex than the mathematical pendulum movement. A complete cycle of particle motion on the inner surface of the cylinder shell consists of 4 phases (Figure 3), namely:

- Relative rest phase (4-1)
- Forward sliding phase (3 - 4)
- Backward sliding phase (1 - 2)
- Free movement phase of (2 - 3).

RESULTS AND DISSCUSIONS

The stable cycle of particle motion, after the 4 phases indicated, is one of the types of motion that refers to the presence of relative rest (type II motion).

Another type of motion is characterized by the fact that it consists only of the sliding phase, the relative rest phase being excluded. In order to highlight the two types of movements we study the influence of the k index, which characterizes the kinematical regimes of the cylindrical shaft, on the position of the four characteristic points and implicitly on the duration of the phases.

Thus, by increasing the k index, the free movement phase decreases due to the proximity of points 2 and 3, and the relative rest phase increases due to the mutual removal of points 1 and 4. At any value of the $k = k_0'$ index, the phase of free movement disappears (points 2 and 3 approach to coincide) and two phases remain: the relative rest phase (1 - 4) and the sliding phase (1 - 2 - 3 - 4).

Increasing the k-value to the limit value k_{lim}, the state of motion does not change; The same phases, slip and relative rest remain (Figure 5.a), which are symmetrical to the vertical diameter. Here of the slip changes qualitatively: if for $k = k_0$ the velocity Ω of the surface, the particle motion ω is less than the velocity ω is delayed).

In Figure 5.a, the particle behavior will again be tracked when the index k value decreases. In this case, the height of the detachment point 2, characterized by the angle β_2 will decrease. The point 4 will approach the lower point M_0 until it coincides with it. This will happen to such a kinematical regime whose index is denoted by k*. Thus, the k* index will be the smallest index at which the relative rest phase still remains, because in a continuous motion of k, point 4 must move further and pass into the first dial, from where the state relative rest can not begin.

So if the relative rest phase does not start at the lowest point then the relative rest state will be entirely excluded. On this basis, the kinematic regime, determined by the k * index, is the limit regime: for k> k * the relative rest phase will remain stable throughout the cycle, and for k <k * will be totally excluded.

If the k * index is considered small enough, the movement becomes immediately unstable, and the relative rest phase disappears; Point 2 will gradually descend to the horizontal diameter and in this case the free movement will be removed, leaving only one phase - the slip. The state of this phase tends to remain constant: the absolute-moving particle will gradually execute a dampened oscillation around a certain point of the $M\varphi$, which eventually touches it.

The position of the $M\varphi$ point will be determined by the center angle equal to the friction angle (Figure 5.a). Therefore, the presence of the kinematic resting state corresponding to the k > k* index creates the characteristic cycle of the circular motion of the particle on the surface of the cylinder.

If a particle mass is loaded on a rotating surface with the indicated regime, then all of this mass will flow to the surface and will have the same circular motion in a layer of thickness equal to the seed thickness. Previously such a movement was assimilated to the second kind of movement. The second kind of movement, viewed from the front of the cylinder covered with a transparent disk, is turbulent (vortices). Because of the high particle velocity, they can not be distinguished by the naked eye. Only thin lines are seen on the entire periphery of the cylinder, which, to a greater or lesser extent, is removed from the surface of the cylinder in the area of the third dial.

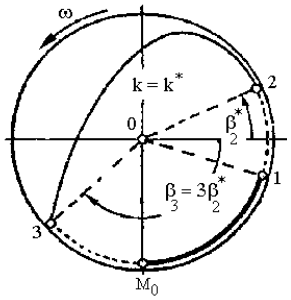

Figure 4 Regime at the limit

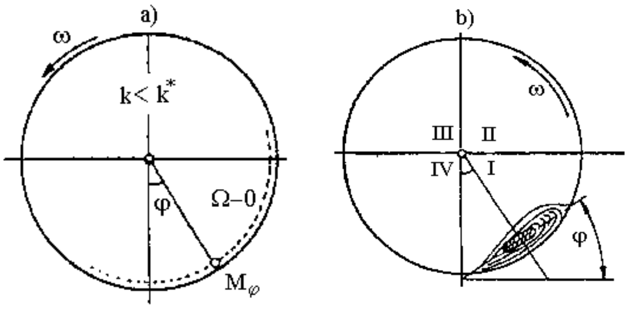

Figure 5 Type I regimes
a) for single particle; b) for a mass of particle.

The limit mode determined by the $k = k^*$ index still characterizes the second kind of motion, but it is sufficient to move the cylinder velocity (when $k<k^*$) sufficient for the particle motion to change sharply and gradually to a mobile equilibrium represented in Figure 4. This movement is assimilated to the first kind of motion.

The first kind of movement is characterized by great stability. In those cases where the entire mass of particles is trained, all are concentrated in the first dial (Figure 5.b) forming a layer of a certain shape and size. This layer is also in a movable balance, occupying a certain position: the middle of the layer lies at the height of the center angle, equal to the φ friction angle.

The seed in the layer does not remain at rest but is trained in a complex motion, basically rotating around an axis parallel to the axis of the cylinder, not on the circular trajectories, but on certain trajectories within the layer. In this case, the row of grains coming into contact with the surface of the cylinder moves at a low speed, but higher than the grains that are in the ranks above. The speed of the lines above decreases gradually and the center of the layer is canceled. In the area above the central core, the seeds move by crumbling, the character of their movement being even more complex, but after the shape the general character of the grain movement inside has the appearance of a whirlpool, the position of the particles differing drastically from the second kind of movement.

It should be noted that this passage, if the strictly geometric and precisely centered cylindrical surface is concerned, is an irreversible process. The particle in the mobile equilibrium state will not modify this state in reverse by the limit regime and will remain in this position for the $k > k^*$ regime. In those cases where the surface of the alveolar cylinder deviates from geometric precision and is not properly centered, which complicates the transport movement, the particle will not have a steady position, having to oscillate around it.

If, from a geometric point of view, the cylindrical surface is properly constructed and precisely centered, because the surface is not continuous due to the practice of the alveoli, the probability of achieving the equilibrium position is even smaller. In these cases, the particle hitting the edges of the cylinder will make uneven jumps and will not be able to reach the steady state of balance. By increasing the velocity of the cylinder, the blows will be more and more powerful, which will increase the particle velocity, this velocity reaching the speed of the cylinder and finally the relative resting state and the second kind of motion. Therefore the transition from the second movement (relative rest) to the first movement is irreversible for discontinuous cylindrical surfaces.

CONCLUSIONS

Besides gravity forces, centrifugal forces and inertia forces act on the particles (seeds). The higher the centrifugal forces, the more centrifugal acceleration will be. However, the higher the kinematical k, the lower the seed sliding phase on the cylinder surface. At the limit value k * the relative rest appears. This contradiction illustrates the small values of the k index and the low yield of the indented cylinder. Any attempt to increase the rotation speed of the cylinder, or its diameter, results in the sliding phase decreasing with the simultaneous increase of the relative rest phase and in reducing the yield of the indented cylinder.

Since centrifugal forces appear during the work due to the rotation of the cylinder, the cylinder speed is limited depending on its diameter. At a high a centrifugal force, the centrifugal forces are higher than the weight of the seeds, so they stick to the inner surface of the cylinder and remain at relative rest to the cylinder. Separation is therefore no longer possible. Depending on the diameter of the cylinder, the required speed will be chosen so that the seed will detach from the inner surface of the cylinder and the separation will take place in optimal conditions.

The hourly productivity increases if the tilt angle of the cylinder increases. However, the tilting of the cylinder is limited by the calibration quality (degree of purity); At a high gradient, the seed passing through the cylinder decreases and the separation is not completely accomplished. Therefore, in order to increase productivity, it is advisable to limit the angle of inclination of the cylinder (depending on the speed of the seed flow) and to increase its length.

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