MOTION INVESTIGATION OF PARTICLES ON VIBRATIONAL FLAT SIEVES

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Abstract: *The flat sieves are often used in agricultural processes of seed separation at harvester reapers, as well as at seed conditioning. The operation of separation of seeds is realized due to the vibration of flat sieve. The material can be schematized by a simple material particle which moves with friction on the vibrating surface. There are analyzed displacement regimes of particle by forward sliding, back sliding and detachment. Because of velocity discontinuity which appears as consequence of friction between particle and plan or of dropping on plan in the case of detachment, vibro-impact motion regimes appear. That is why, for the study of motion, there are applied the specific methods, concerning the vibro-impact regimes. It must underline that in some processes of vibro-transfer, motions with detachments can appear and also, droppings of particle on the vibrating plan. There are taken into consideration only vibration displacements with sliding on the vibrating plan, which have vibro-impact character because of the discontinuity of friction force. The motion investigation of particle on flat sieve is analyses by the aid of motion parameters: the angle of gradient of the shaking surface, the angle between the direction of the shaking and the surface, the sliding friction coefficient, the angular velocity etc. Forward, the differential equations of the movement are established and the mathematical apparatus are developed in order to obtain the charts which emphasize and limit different possible dynamic regimes. The obtaining of this charts is computerized, therefore, with the help of a computer program it is possible the specification of the parameters which leads to realization of some optimum dynamic regimes. The work have a real interdisciplinary character because requires large knowledge of mechanics, agricultural machines, mathematics and computer programming.*

Key words**:** *flat sieves, vibrational transport, particle, relative motion, optimum parameters*

INTRODUCTION

The flat sieves are often used in agricultural processes of seed separation at harvester reapers, as well as at seed conditioning.

The operation of separation of seeds is realized due to the vibration of flat sieve. The operation of separation is analyzed with the help of the particle model which executes vibration motions on a plane with friction.

There are analyzed displacement regimes of particle by forward sliding, back sliding and detachment. Because of velocity discontinuity which appears as consequence of friction between particle and plan or of dropping on plan in the case of detachment, vibro-impact motion regimes appear. That is why, for the study of motion, there are applied the specific methods, concerning the vibro-impact regimes.

It must underline that in some processes of vibro-transfer, motions with detachments can appear and also, droppings of particle on the vibrating plan. This kind of regimes is of the nature of vibro-impact phenomena and forms a special domain of study.

For the beginning, there are taken into consideration only vibration displacements with sliding on the vibrating plan, which have vibro-impact character because of the discontinuity of friction force.

MATERIAL AND METHODS

Generally, the phenomenon of vibro-transfer is essentially influenced by the material behavior, characterized by composition, humidity, adherence, nature, etc. In the first approximation, the experiences shown that the material can be schematized by a simple material particle which moves with friction on the vibrating surface (Figure 1).

It is supposed that the vibrating plan executes a vibration translation according to $r\sin\omega t$ law. Angle α is named the angle of gradient of the shaking surface and the angle between the direction of the shaking and the surface is named β. In Figure 1 we can see the forces which are necessary to be taken into consideration during the studying of the relative motion of the grain on the moving surface.

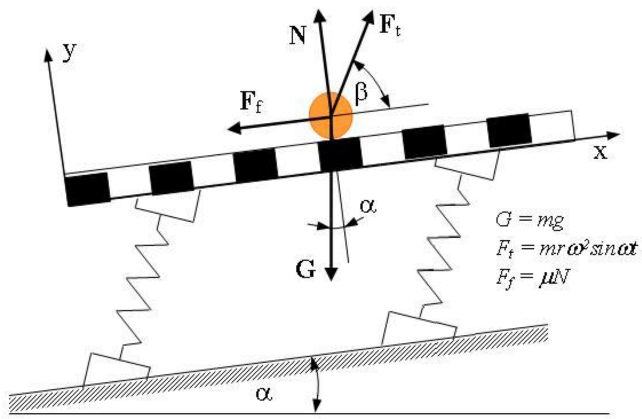

Figure 1. The acting forces on the grain

The differential equations of the relative motion are

$$m\ddot{x} = mr\omega^2 \cos\beta \sin\omega t - mg \sin\alpha - \mu N \qquad (1)$$

$$m\ddot{y} = N - mg \cos\alpha + mr\omega^2 \sin\beta \sin\omega t \qquad (2)$$

where $\mu = tg\varphi$ is the sliding friction coefficient.

If the grain stays on the moving surface $y = \dot{y} = \ddot{y} = 0$ and from equation (2)

$$N = mg \cos\alpha - mr\omega^2 \sin\beta \sin\omega t \qquad (3)$$

In order that the grain may really stay on the surface it is necessary for the $N > 0$ relation to be realized in every moment of the motion. This condition is realized if

$$\frac{r\omega^2}{g} < \frac{\cos\alpha}{\sin\beta}. \qquad (4)$$

The grain will stay in motionless position, while the magnitude of the transport force reaches the value by which the forces become unbalanced. From here we derive the condition

$$\frac{r\omega^2}{g} > \frac{\sin\alpha + \mu_o \cos\alpha}{\cos\beta + \mu_o \sin\beta} \qquad (5)$$

If the condition (5) is realized in a given time-point t_1, the grain begin to slide upwards on the surface. The value of t_1 can be obtained from the equation

$$sin\,\omega t_1 = \frac{g}{r\omega^2}\frac{sin\,\alpha + \mu_o\,cos\,\alpha}{cos\,\beta + \mu_o\,sin\,\beta}\,. \tag{6}$$

From this moment the differential equations (1)-(2) are valid. Supposing that in the relative motionless position of the grain $x = x_0$, the initial conditions of the motion are

$$t = t_1,\ x = x_o,\ \dot{x} = 0\,. \tag{7}$$

By substituting the function N from equation (3) for equation (1) we can get the next differential equation:

$$\ddot{x} = -\frac{sin(\,\alpha+\varphi\,)}{cos\,\varphi}g + \frac{cos(\,\beta-\varphi\,)}{cos\,\varphi}r\omega^2\,sin\,\omega t\,. \tag{8}$$

After the integration of equation (8) the velocity of the relative motion can be obtained:

$$v_r = -\frac{sin(\,\alpha+\varphi\,)}{cos\,\varphi}g(\,t-t_1\,) + \frac{cos(\,\beta-\varphi\,)}{cos\,\varphi}r\omega(cos\,\omega t_1 - cos\,\omega t\,)\,. \tag{9}$$

The relative motion forwards will be finished at moment t_2 when the difference of velocities of the grain and shaking surface becomes zero. The value of timepoint t_2 can be determined by the aid of the next equations:

$$cos\,\omega t_1 - cos\,\omega t_2 = \frac{g}{r\omega}(t_2 - t_1)\frac{sin\,\alpha + \mu\,cos\,\alpha}{cos\,\beta + \mu\,sin\,\beta}\,. \tag{10}$$

The relative position-time function between t_1 and t_2 timepoints can be obtained after repeated integration of equation (9):

$$\begin{aligned} x = x_o - \frac{sin(\,\alpha+\varphi\,)}{cos\,\varphi}g\frac{(\,t-t_1\,)^2}{2} + \\ \frac{cos(\,\beta-\varphi\,)}{cos\,\varphi}r\left[\omega(\,t-t_1\,)cos\,\omega t_1 + sin\,\omega t_1 - sin\,\omega t\right] \end{aligned}\,. \tag{11}$$

According to equation (11) the traveled distance between t_1 and t_2 timepoints on the moving surface is:

$$\begin{aligned} \Delta x = x(\,t_2\,) - x(\,t_1\,) = -\frac{sin(\,\alpha+\varphi\,)}{cos\,\varphi}\frac{g\Delta t^2}{2} + \\ \frac{cos(\,\beta-\varphi\,)}{cos\,\varphi}r(\,\omega\Delta t\,cos\,\omega t_1 + sin\,\omega t_1 - sin\,\omega t_2\,) \end{aligned}\,, \tag{12}$$

where $\Delta t = t_2 - t_1$.

After timepoint $t = t_2$ the grain will stay temporarily in relative motionless position again, some time later it will start upwards or downwards in function of changing of acting forces. If the sense of force F_t changes ($sin\,\omega t < 0$), the tendency of the motion shows downwards. This motion cannot be realized if

$$\frac{r\omega^2}{g} < \frac{\mu_o \cos\alpha - \sin\alpha}{\cos\beta - \mu_o \sin\beta}. \tag{13}$$

If this condition will be realized, then the grain will not start downwards on the shaking surface, from relative motionless position it will start upwards again, namely towards the direction of transport after some time. In this case the grain travels in equation (12) calculated distance during a period of the exciting, so the average speed of the grain is

$$v_{rav} = \frac{\Delta x}{T} = \frac{2\pi\Delta x}{\omega}. \tag{14}$$

On the basis of the above mentioned the investigated motion (sliding only towards the direction of transport) can be realized, if relation (4) and at the same time the relations (5) and (13) satisfy

$$\frac{\sin\alpha + \mu_o \cos\alpha}{\cos\beta + \mu_o \sin\beta} < \frac{r\omega^2}{g} < \frac{\mu_o \cos\alpha - \sin\alpha}{\cos\beta - \mu_o \sin\beta}. \tag{15}$$

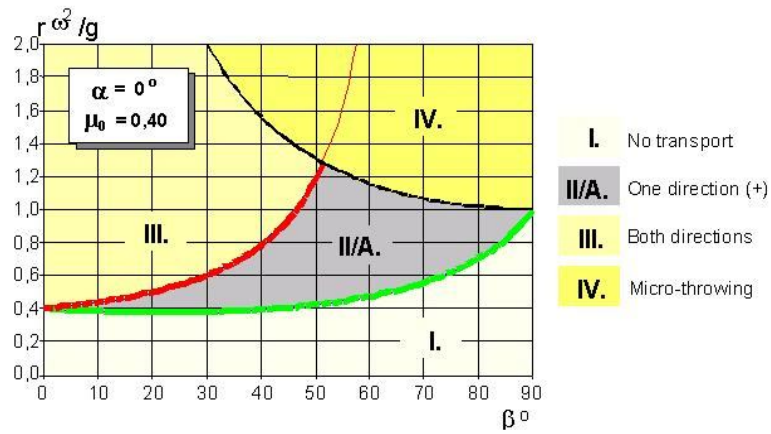

Figure 2 The possible motions of the grain

On the basis of relations (4), (5) and (13) the motion characteristics can be studied in Figure 2 in the plain of parameters β and rω^2/g, if α = 0 is μo = 0,4. In the zone marked by dark shading the grain can slide in only one direction (low-speed running), namely in zone II/A in the direction of transport and in zone II/B in the opposite direction. In zone III, the grain can slide in both directions (quick-speed running), and in zone IV it leaves the shaking surface from time to time, after that it is free to move while it reaches the surface again (micro-throwing transport). As it can be seen, one-way direction motion can be only realized, if the value of rω^2/g is between determined boundaries.

RESULTS AND DISCUSSIONS

As it can be seen during the studying of the simplest motion we have to take several circumstances into consideration and solve transcendent equations. For this reason it would be very difficult to investigate the effect of change of one of all parameters, for example, on the average velocity of transport.

In order to surmount the above-mentioned difficulties, they are established a computer program to investigate the possible motions. After giving the parameters: r, ω, α, β, μo, μ the computer shows which type of motion will be realized, on the screen the simulation of the motion can be studied and the computer determines the average velocity of the relative motion of the grain. In this way the possible motion types can be easily investigated and the change of the average velocity in function of different parameters can as well be analyzed. By the aid of this program we can determine the optimum parameters of vibrating transport.

Figure 3 shows the motion types in the case of $\alpha = +5^{O}$, and $\alpha = -5^{O}$. On the right hand-side of Figure 3 the changing of the average velocity can be seen in function of angle β.

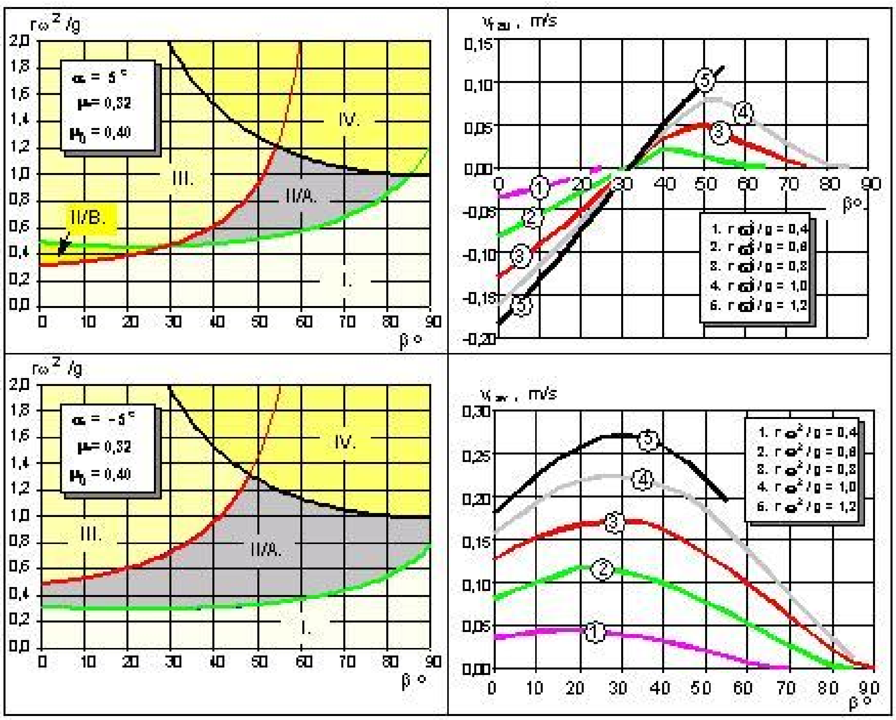

Fig. 3 Different motion types

If the angle of the shaking surface is positive ($\alpha = +5^{O}$), the supposed direction of the transport is upwards on the surface, besides the zone II/A there is an other zone (II/B) in which the grain can slide only in one direction, but it is negative. Otherwise in such cases the sense of the average velocity of the transport is also negative by little values of angle β.

If $\alpha < 0^{O}$ (for example $\alpha = -5^{O}$), when the positive sense sets downwards on the surface, the zone II/B disappears and the zone II/A will be greater. In such cases the sense of the average velocity of the transport will be positive by every value of angle β and much greater than in previous cases.

The motion types can be investigated if the angle β between the direction of the vibration and the surface is constant and they are modify the value of α step by step.

CONCLUSIONS

If the direction of shaking is the same with the surface (β=0), then motion in direction of transport is possible only in case of negative values of angle α.

If β>0 (for example $\beta=40^O$), motion in positive direction can be realized as well, if α>0.

In both cases if angle α is growing, as a result the average velocity of transport is decreasing.

By the aid of used program these investigations can be made with any values of parameters α, β, μo, μ.

This paper clearing the possible motion of the single grain in function of the motion influencing parameters putting it on the shaking surface. By the aid of the developed program it is very easy to clear the circumstances of motions and determine the average velocity of transport in function of influential parameters of motion and hereby the optimum circumstances of vibrating transport.

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