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EVALUATION OF THE LEVEL OF PERFORMANCE FOR THE VIBRATING SCREENS BASED ON DYNAMIC PARAMETERS

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Abstract: *The level of technological performance for inertia vibrating screens is determined by functional and technological constructive parameters, so that the efficiency of granular materials sieving to be ensured based on granulometric curves experimentally plotted in laboratory In order to do it, the determined parameters of the vibrating screen have to be set while the technologic process is on, as well as to be set to certain values depending on the granular material type. This is the case when the inertia vibrating screens, with inclined position relative to the horizontal axis, is characterized by two decoupled motions with same excited pulsation, so that vibrations along the two rectangular axes, horizontal and vertical, could determine a helical trajectory of the vibrating screen. That is why, in this paper there was determined a calculus approach to the dynamic model and the conditions for optimum sorting the mineral aggregates extracted from water basins (river gravel) or, from stone carriers [1,4,12,13].*

Key words: *technological vibrations, vibrating screen, dynamic model, performance dynamic parameters.*

1. INTRODUCTION

For the inclined vibration screen used in sorting process, there was determined a two degrees of freedom dynamic model, on the horizontal and vertical axes, with decoupled vibrations, due to the fact that the supporting and damping elastic elements along the two directions are independent. The phenomena of sieving on vibrating screens is complex and difficult to study because of the high number of parameters of the operating process. This is why, experimentally it has been concluded that the sieving efficiency and productivity of the vibrating screen represent the technological capability characteristics that are significantly influenced by vibrations frequency and amplitude.

For this case, the sieving process study is based on the study of vibrations frequency and amplitude, inclination angle of the vibrating screen, its trajectory, as well as of sieves dimensional parameters – length, width, and their number. Also, an important role is that of the post resonance motion regime of the vibrating screen while technological process is on [1,2,4,5,7,13].

2. DYNAMIC PARAMETRS STUDY

The calculus approach of the dynamic model consists in the schematization of a vibratory screen with inertia excitation by a disturbing rotating force, inclined by the angle $\alpha = 10^o$ – 20^o and equipped with two, up to four, sieves, according to the scheme in figure 1 [8,9,10,12].

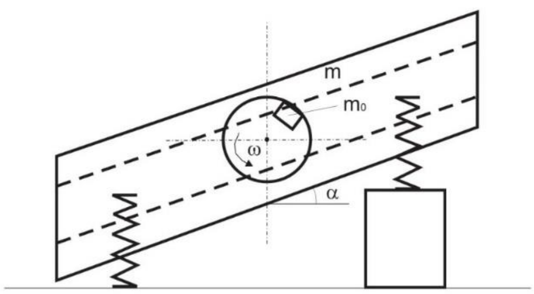

Fig 1 Scheme of the inertia vibrating screen in inclined position

The vibrations generator has an unbalanced mass that generates a disturbing rotating force with constant modulus at the operating angular velocity, in post resonance regime. The dynamic model of the inclined inertia vibrating screen is shown in figure 2.

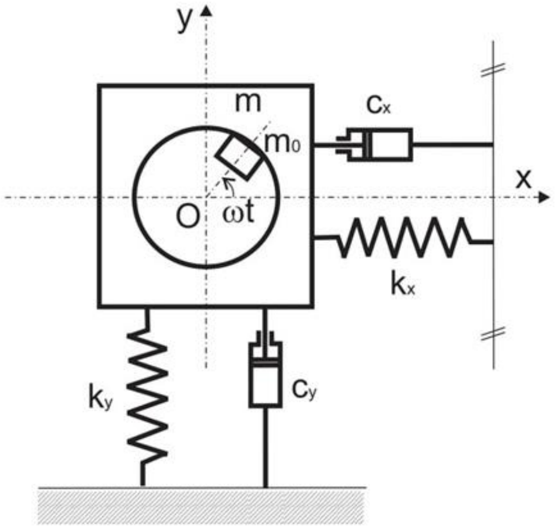

Fig 2 Dynamic model of the inclined inertia vibrating screen

There follows the notation of the representative parameters:

m is the mass of the mobile sieves frame*;*

m_0 – eccentric mass;

ω – angular velocity of the eccentric mass;

p – self pulsation of the sieves frame;

r – eccentricity of the unbalanced mass;

x, y – coordinates of the center of gravity of sieves frame;

k_x, k_y – rigidity of elastic joints on horizontal and vertical directions;

c_x, c_y – damping of elastic joints on the two directions;

$\dot{x}$, $\dot{y}$ – speeds of the mobile frame along the coordinate axes;

$\ddot{x}$, $\ddot{y}$ - accelerations of the mobile frame along the coordinate axess;

F_0 – disturbance centrifugal force;

t – time;

E_c – kinetic energy;

U – force function for elastic forces.

In order to determine the motion differential equations there are applied Lagrange equations as:

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_i}\right) - \frac{\partial L}{\partial q} = Q_i \qquad (i = 1,2) \qquad (1)$$

where: L = E_c + *U is* Lagrange function, and Q_i are the generalized forces that to not result from any force function.

The expressions of kinetc energy and force function derived from the dynamic model are:

$$E_c = \frac{m\,\dot{x}^2}{2} + \frac{m_0}{2}\,(\dot{x} - \omega r \sin \omega t)^2 + \frac{m\,\dot{y}^2}{2} + \frac{m_0}{2}\,(\dot{y} - \omega r \cos \omega t)^2 \qquad (2)$$

$$U = -\frac{k_x\,x^2}{2} - \frac{k_y\,y^2}{2} \qquad (3)$$

where: $q_1 = x$; $q_2 = y$ are the coordinates of the center of gravity of sieves.

If the system gets a virtual displacement along Ox axis, than the virtual mechanical work done by dissipative forces $c_x\,\dot{x}$ and $c_y\,\dot{y}$ is determined by relations:

$$\delta L_x = -c_x \dot{x} \delta x \;; \qquad \delta L_y = -c_y \dot{y} \delta y \qquad (4)$$

The generalized forces Q_1 and Q_2 are expressed by:

$$Q_1 = \frac{\delta L_x}{\delta x} = -c_x \dot{x} \quad ; Q_1 = \frac{\delta L_y}{\delta y} = -c_y \dot{y} \qquad (5)$$

Replacing relations (2), (3), (4) and (5) in (1)it results the system of differential equations as formulas:

$$\begin{cases}(m + m_0)\ddot{x} + c_x\dot{x} + k_x\,x = F_0 \cos \omega t \\ (m + m_0)\ddot{y} + c_y\dot{y} + k_y\,y = F_0 \sin \omega t\end{cases} \qquad (6)$$

or:

$$\begin{cases}\ddot{x} + 2n_x\dot{x} + p_x^2\,x = \frac{F_0}{m+m_0} \cos \omega t \\ \ddot{y} + 2n_y\dot{y} + p_y^2\,y = \frac{F_0}{m+m_0} \sin \omega t\end{cases} \qquad (7)$$

where:

$$p_x = \sqrt{\frac{k_x}{m+m_0}}\,; \quad p_y = \sqrt{\frac{k_y}{m+m_0}}\,;$$

$$n_x = \sqrt{\frac{c_x}{2(m+m_0)}}; \; n_y = \sqrt{\frac{c_y}{2(m+m_0)}} \qquad (8)$$

The solutions of the equations system (7) are:

$$\begin{cases} x = a_x \cos(\omega t - \varphi_x) \\ y = a_y \sin(\omega t - \varphi_y) \end{cases} \quad (9)$$

where the amplitudes a_x, a_y are determined by relations:

$$a_x = \frac{m_0\, r\omega^2\, \cos\alpha}{(m+m_0)\sqrt{(p_x^2-\omega^2)^2+4n_x^2\omega^2}};$$

$$a_y = \frac{m_0\, r\omega^2\, \sin\alpha}{(m+m_0)\sqrt{(p_y^2-\omega^2)^2+4n_y^2\omega^2}} \quad (10)$$

and the angular phase shifts φ_x and φ_y are expressed by:

$$\operatorname{tg}\varphi_x = \frac{2n_x\omega}{p_x^2-\omega^2};\ \operatorname{tg}\varphi_y = \frac{2n_y\omega}{p_y^2-\omega^2} \quad (11)$$

$$\varphi_x = arctg\frac{2n_x\,\omega}{p_x^2-\,\omega^2} + k\pi;$$

$$\varphi_y = arctg\frac{2n_y\,\omega}{p_y^2-\,\omega^2} + k\pi; \quad k\in Z.$$

For the customized case when the system's dampings are neglected, meaning $c_x \cong c_y \cong 0$, from relation (9) it results the equation of the mobile frame mass center trajectory relative to a referenatial system Oxy positioned in the oscilation center, figure 3, as follows:

$$\frac{x^2}{a_x^2} + \frac{y^2}{a_y^2} = 1 \quad (12)$$

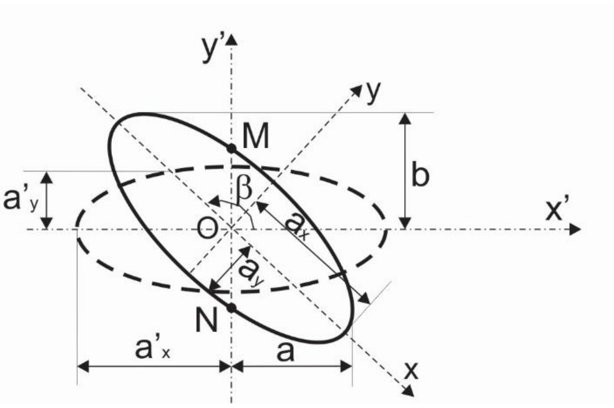

Fig.3 Elliptical trajectory of the mobile frame for the general case ($c_x \neq c_y \neq 0$) and the customized case ($c_x = c_y = 0$)

Relation (12) to system Ox'y' is the equation of an horizontal ellipse, dot shown in figure 3, with the semi-axes a'_x and a'_y as follows:

$$\begin{cases} a'_x = \dfrac{m_0 r\omega^2}{(m+m_0)(p_x^2-\omega^2)} \\ a'_y = \dfrac{m_0 r\omega^2}{(m+m_0)(p_y^2-\omega^2)} \end{cases} \quad (13)$$

With the notation u=$\frac{m_0}{m+m_0}$, relation (13) could be re-written as:

$$a'_x = \frac{ur\omega^2}{p_x^2-\omega^2};\ \ a'_y = \frac{ur\omega^2}{p_y^2-\omega^2} \quad (14)$$

Under the assumption that the angular shifts φ_x, φ_y are zero, the customized solutions for the equation (7) are:

x=$a_x cos\omega t$; y=$a_y sin\omega t$; (15)

or

$$x = \frac{ur\omega^2}{p_x^2-\omega^2}cos\omega t;\ \ y = \frac{ur\omega^2}{p_y^2-\omega^2}sin\omega t \quad (16)$$

Most of the times, the vibrating screen operates in post resonance regime and, thus, the square of vibrations frequency $p^2$is very low when compared to the square of forced vibrations frequency ω^2 and can be neglected. In this situation, the maximum amplitude of sieves frame is determined from relations (15) and (16) as follows:

a(m+m_0)=$-\ m_0 r$ (17)

Physical size $m_0 r$ determines the static momnet of the vibratory eccentric. The minus sign in the first part of equation (17) proves for the fact that, for the post resonance regime, the motion of sieves frame is in pahes shift with the disturbance force. This is to be considered for the design of motion transmission system, from the motor to the vibrogenerator, in order to ensure the self reguation conditions [2,3,6,11,13].

If the motion regime, along both directions, is within the pre resonance, or post resonance regime, then $\frac{p_x^2-\omega^2}{p_y^2-\omega^2} > 0$, and thus resulting from relations (9)-(11) the fact that points of the sieves mobile frame move along their trajectories in the direction of rotation of the unbalanced mass.

If, along one of the two directions the motion regime is pre resonance, and along the other direction is post resonance, then $\frac{p_x^2-\omega^2}{p_y^2-\omega^2} < 0$ and points of the sieves mobile frame move along their trajectories in the reverse direction of rotation of the eccentric.

In general case, the mobile frame has motions along elliptical trajectory whose axes are not the same as those of coordinate system's axes. The ellipse equation is given by relation:

$$\frac{x^2}{a_x^2} + \frac{y^2}{a_y^2} - \frac{2xy}{a_x \cdot a_y} \sin(\varphi_y - \varphi_x) = cos^2(\varphi_y - \varphi_x) \quad (18)$$

The vibration amplitudes of the mobile frame along Ox axis and, respectively, Oy (fig.3) are:

$$a = \frac{a_x a_y |\cos(\varphi_y - \varphi_x)|}{\sqrt{\frac{1}{2}(a_x^2 + a_y^2) - \frac{1}{2}(a_x^2 + a_y^2) cos2\beta - a_x a_y \sin(\varphi_y - \varphi_x) sin2\beta}}$$

$$b = \frac{a_x a_y |\cos(\varphi_y - \varphi_x)|}{\sqrt{\frac{1}{2}(a_x^2 + a_y^2) + \frac{1}{2}(a_x^2 + a_y^2) \cdot cos2\beta - a_x a_y \sin(\varphi_y - \varphi_x) sin2\beta}} \quad (19)$$

where β is the angle between identical semiaxes of the two ellipses (fig.3).

When $|\varphi_y - \varphi_x| < \pi/2$, the direction of motion for the mobile frame is the same with the eccentirc mass rotational motion direction.

When $|\varphi_y - \varphi_x| > \pi/2$, the mobile frame moves opposite to the eccentirc rotational motion direction.

When $|\varphi_y - \varphi_x| = \frac{\pi}{2}$, the elliptical trajectory degenerates into a linear trajectory with amplitude $a_1 = \sqrt{a_x^2 + a_y^2}$ and inclination angle $\beta_1 = arctg\left[\frac{a_y}{a_x} \sin(\varphi_x - \varphi_y)\right]$

In the particular case when $a_x = a_y$ și $\varphi_x = \varphi_y$ the trajectory of the mobile frame is circular with the same rotational direction as that of the eccentric. Obvious, the situation occurs only when $c_x = c_y$ și $k_x = k_y$ [3,4,5,6,7].

3. CONCLUSION

The dynamic model for vibrating screen operating in inclined position relative to the horizontal axis, is characterised by the fact that it is schematically presented as a body with the same mass as that of the vibrating screen and having the rotational center of the eccentric mass the same as the gravitational center of the screen. Also, both elastic and viscous bonds are equivalent to the two rectangular directions of the vertical plane where the rotational motion of the rotational force generated by the eccentric mass takes place.

This is the case when the sorting equipments are modelled as a mass with independently two degrees of freedom, meaning that motions along horizontal and vertical axes are fully decoupled.

Based on the experimental results for three types of vibrating screens CV4; CV8; CV12, with sieve's surface of 4 m², 8 m² and, respectively, 12 m², that have previuosly been designed, experimented and homologated, the resulting concluisons are:

a) the linear model of the inclined vibrating screen, with a disturbance centrifugal force applied in the center of gravity of the screen, stands as the basis for dynamic calculus approach and parametric evaluation that ensures a significant level for the dynamic behaviour;

b) the analysis of dynamic parameters that consists in determination of amplitude along the two directions, direct correlated to the sorting technological frequency,points out that the trajectory for each point of the sieves is elliptical or, in particular, could be circular only when the rigidities and dampings along the two directions are equal;

c) the determined calculus relations are worth both for the optimization of the operating dynamic regime so that to be ensured an optimum sieving regime and for the required parametrs setup in situ, depending on the charactersitics of mineral aggregates and of screen installation and assembly system.

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EVALUAREA PARAMETRICĂ A CIURURILOR VIBRATOARE PENTRU ASIGURAREA PERFORMANȚEI SORTĂRII AGREGATELOR MINERALE

Rezumat: *Nivelul de capacitate tehnologică pentru ciururile vibratoare inerțiale se stabilește pe baza parametriilor constructivi funcționali și tehnologici astfel încât eficiența cernerii materialelor granulare să poată fi asigurată pe baza curbelor granulometrice determinate pe cale experimentală în laborator. Pentru aceasta parametrii determinați ai ciurului vibrator trebuie să poată fi reglați atât în timpul procesului tehnologic cât și stabiliți la valori fixe în funcție* de natura materialului *granular. În acest context ciururile vibratoare inerțiale cu poziție înclinată față de orizontală se caracterizează prin două mișcări decuplate cu aceeași pulsație de excitație astfel încât vibrațiile după axele rectangulare orizontală și verticală să poată duce la o traiectorie eliptică a ciurului vibrator. Pentru aceasta în prezentul articol a fost stabilit modelul dinamic de calcul precum și condițiile de realizare a regimului optim de funcționare pentru realizarea unei eficiențe* maxime de *sortare a agregatelor minerale de carieră și balastieră.*

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