APPLICATION OF SIEVING PROCESS OF VIBRATORY SCREEN

Gheorghe I. ENE
POLITEHNICA University of Bucharest, E-mail: ghene01@yahoo.com

Abstract*: In this work are presented the conjugated influences on the sieving process of two elements: the friction between the sift material and screen and locking mesh of sieve with grains unable to cross the screen. The functional characteristics of the vibrating screen are determined, observing the influence of these factors upon the sieving process.*
Key words: *sieving process, vibratory screen*

1. THE DETERMINATION OF FUNCTIONAL CHARACTERISTIC OF THE SCREEN

We consider a screen with siev inclined with angle β against horizontal, realize vibrations after linear trajectory which form the throwing angle γ with direction of the screen (angle α with horizontal) (linear vibration). The screen take action with the help of a vibrations generator with crank gear (mechanism with eccentric).

The working condition to work with moving of material by sliding on screen[3, 5].

a. *The up working of the material on the screen*
Forces acting on material grain in this case are presented in figure 6.

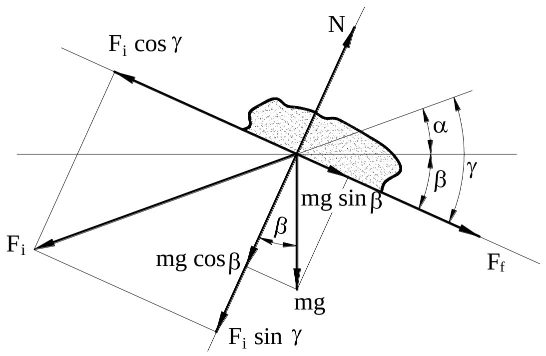

Fig. 6. Forces acting on up moving grain on screen

The grain is upsliding on screen if condition is executed (fig. 6):

$$F_i \cdot \cos\gamma - m \cdot g \cdot \sin\beta \ge F_f \, . \tag{1}$$

Taking consideration that the inertia force has the expression: $F_i = m \cdot r \cdot \omega^2$ (2)
and friction force:

$$F_f = m \cdot \left(g \cdot \cos\beta + r \cdot \omega^2 \cdot \sin\gamma\right) \cdot tg\varphi \tag{3}$$

from relation (2) we obtain:

$$K_d = \frac{r \cdot \omega^2}{g} \ge \frac{\sin(\varphi+\beta)}{\cos(\varphi+\gamma)} \tag{4}$$

The revolution of crank (eccentric) of the action mechanism for witch the condition (4) is realized, is determined by the relation:

$$n \ge \frac{30}{\pi} \cdot \sqrt{\frac{g}{r} \cdot \frac{\sin(\varphi+\beta)}{\cos(\varphi+\gamma)}} \quad rot/min \tag{5}$$

(r is expressed in m, and g in m/s^2).

b. The motion down on the screen
The forces acting upon the grain of material, when this is sliding down, on the
screen, are presented in figure 7.

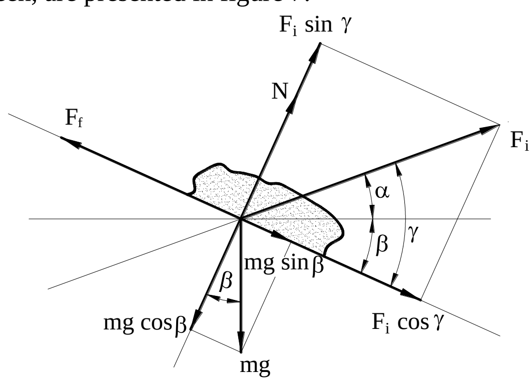

Fig. 7. Forces acting upon the grain down mowing on screen.

Proceeding as in the previous case, is determined the condition of grain down sliding on screen:

$$K_d = \frac{r \cdot \omega^2}{g} \ge \frac{\cos(\varphi-\gamma)}{\sin(\varphi-\beta)} \tag{6}$$

The revolution of the crank for which is executed (18) is:

$$n \ge \frac{30}{\pi} \cdot \sqrt{\frac{g}{r} \cdot \frac{\sin(\varphi-\beta)}{\cos(\varphi-\gamma)}} \quad rot/min \tag{7}$$

To imped the grains to block the holes of screen, in both situations, it is necessary to be executed condition .
The moving of grain by jumps on screen [3, 5]
From the equation of formal equilibrum of forces, after the normal direction to screen, result:

$$N = m \cdot \left(g \cdot \cos\beta - r \cdot \omega^2 \cdot \sin\gamma\right) \tag{8}$$

The grain will detach from screen when its pressing on this become null, meaning:

$$g \cdot \cos\beta - r \cdot \omega^2 \cdot \sin\gamma = 0 \tag{9}$$

The condition (6) may be as forms:

$$K_d = \frac{r \cdot \omega^2}{g} = \frac{\cos\beta}{\sin\gamma} \tag{10}$$

respectively: $\frac{r \cdot \omega^2}{g} \cdot \frac{\sin\gamma}{\cos\beta} = 1$ (11)

Size: $C_a = \frac{r \cdot \omega^2}{g} \cdot \frac{\sin\gamma}{\cos\beta}$, (12)

representing the throw coefficient (the ration between normal components at screen of the inertia force and of the grain weight) and characterize the working condition of the screen with detach of the material from the sieve.
The working condition with detach of the material from the screen happen for:

$$C_a \geq 1. \tag{13}$$

Using one of the relation (10) or (11) the revolution of mechanism connecting rod–crank for training is:

$$n \geq \frac{30}{\pi} \sqrt{\frac{g}{r} \cdot \frac{\cos\beta}{\sin\gamma}} \qquad rot / min \tag{14}$$

The problem is how big can by the value of the throw coefficient, because when these values are growing, the oscillations of the screen become very energetic, with negative consequences, like: growing of mechanical solicitations of the component elements of the screen, as following the inertia forces; diminution of quality of sieving (because of large jump of grains, which cross the screen more quickly).
The throw coefficient must have a value that the material passed through screening must be spared, the sieving quality must be corresponding and the screen must be not bottomed by fixing of the grains ″difficult″ in holes.
A good quality of screening is realised when we touch the ″statistical resonance″, meaning when the grain detach at every oscillation of the screen (the duration of the jump of grain is equal to period of oscilation of the screen), because in this case, the number of statistical comparison between the dimensions of grain and of holes of screen is the highest.
For the grain can jump in the following holes, the height of jump of grain must accomplish (see fig. 8) [1, 3]:

$$h_0 = \frac{v^2}{2 \cdot g} \cdot \frac{\sin\gamma \cdot \cos\alpha}{\cos\beta} \geq \frac{d + d_s}{2} \tag{15}$$

where, d is dimension of the hole;
d_s – diameter of screen wire from cloth (the thickness of the plate, for perforated screen plate);
v – the speed with which the grain lieve the screen.

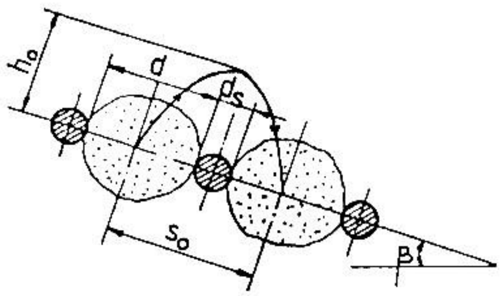

Fig. 8. Parameters of the grain jump.

If we observe that [3, 5]:

$$v = r \cdot \omega \cdot \sqrt{1 - \frac{1}{C_a^2}} \tag{16}$$

in relationship (26), we obtian the screen speed in vibration moving :

$$r \cdot \omega \geq \sqrt{g \cdot (d + d_s) \cdot \frac{C_a^2}{C_a^2 - 1} \cdot \frac{\cos\beta}{\sin\gamma \cdot \cos\alpha}} \tag{17}$$

or the angular speed of the vibrator (the own pulsation of the disturbing force):

$$\omega \geq \sqrt{g \cdot \frac{d + d_s}{r^2} \cdot \frac{C_a^2}{C_a^2 - 1} \cdot \frac{\cos\beta}{\sin\gamma \cdot \cos\alpha}} \tag{18}$$

in which $\gamma = \alpha + \beta$ represent *the throwing angle*.
Considering the expressions (12) and (16), the condition (15) become:

$$h_0 = \frac{r}{2} \cdot \frac{C_a^2 - 1}{C_a} \cdot \cos\alpha \geq \frac{d + d_s}{2} \tag{19}$$

The correlation (30) permit the determination of angle α:

$$\alpha \leq \arccos\left(\frac{d + d_s}{r} \cdot \frac{C_a}{C_a^2 - 1}\right) \tag{20}$$

For the grain jump in the following hole, is necessary to realize the condition (see fig. 7) [3,5]:

$$S_0 = \frac{2 \cdot v_H^2}{g} \cdot \frac{\sin\gamma}{\cos\alpha \cdot \cos^2\beta} \geq d + d_s \tag{21}$$

where $d + d_s$ is the step of holes;
d – their dimensions;
d_s – the diameter of the screen wire from cloth (the small bridge between the holes, for perforated screen).
Comparing the dimensions h_0 and S_0 definite by relation (15) and (21), we observe that :

$$S_0 = \frac{4 \cdot h_0}{\cos\beta} \tag{22}$$

The dimension of the angle β is adopted constructive observing the following specifications.
The screen is put in horizontal plane or inclined with an angle β face to this. The angle β must be smaller than friction angle between material and screen (to keep the material to slide from the screen when this is nut in function). More the value of β angle is reduced, more the quality of the seering is better, because in this situation, the lenght of grain jump is smaller (and, consequently, bigger number of statistic comparisons between dimensions of grain and of the screen hole, during the material cross the screen) and the angle of down fall of the grai non screen (that guide to increase the probability of passing the grains through the screen holes).
The screen with large holes need high values for the amplitude of oscillation and of coefficient of throwing.
The amplitude of the oscillatory movement is adopted screen holes taking into consideration that screens with big holes need bigger amplitudes to realize a jump big enough which will assure the passing of grain from hole to hole. We recommend utilization of values from table 2 [3, 5].

Table 2. Values of parameters of oscillation.

Dimensions of holes, mm	6	12	22	45	70
Amplitude oscillation, A = r, mm	5	7.5	10	12.5	20
Revolution of crank, rot / min	800	710	700	690	620

The coefficient of throwing is essential dimention for the correct functional for screen The practical experience recommend for oscilatting screen the following values of the throwing coefficient [3, 5]:

- $C_a = 1,3 \dots 1,6$ – for friable materials (witch can by break during the screening);
- $C_a = 1,7 \dots 2,0$ – for materials witch are not breaking during the screening;
- $C_a = 2,0 \dots 2,4$ – for sticky materials, witch have tendency to bottom the screen.

Knowing the values of throwing coefficient, the angular speed of the mechanism of training crank gear is determined by relation:

$$\omega = \sqrt{C_a \cdot \frac{g}{r} \cdot \frac{\cos\beta}{\sin\gamma}} \ , \ s^{-1} \qquad (23)$$

and revolution with relation:

$$n = \frac{30}{\pi} \cdot \sqrt{C_a \cdot \frac{g}{r} \cdot \frac{\cos\beta}{\sin\gamma}} \ . \quad rot/min \qquad (24)$$

5. NUMERICAL EXEMPLE

From a material with many dimension, we must obtain, by sifting two fractions. The separation dimension, the granulometric characteristics of material and the form of grains impose the adoption of a screen mesh with square holes STAS 1077 with opening of the hole $d = 6,3\ mm$ and the diameter of the wire of mesh $d_s = 1,25\ mm$.

The material is not friable, but has the tendency to put a bottom to the screen by fixing the ″difficult″ grains in holes, so that we adopt the conditions of movement by jump, the throwing coefficient with size $C_a = 2.2$.

For the radius of the crank we adopt, depending on opening of holes $d = 6.3\ mm$, value $r = 5\ mm$ (table 2).

Result the value of angle α:

$$\alpha = arc\cos\left(\frac{d + d_{sd}}{r} \cdot \frac{C_a}{C_a^2 - 1}\right) = 30^\circ$$

We adopt the value $\alpha = 25°$.

For angle β we adopt $\beta = 10°$.

The height of grain jump in the presence of screen is:

$$h_0 = \frac{r}{2} \cdot \frac{C_a^2 - 1}{C_a} \cdot \cos\alpha = 4\ mm$$

It is executed the condition:

$$h_0 = 4\ mm > \frac{d + d_s}{2} = 3{,}7\ mm$$

The length of grain jump on screen:

$$S_0 = \frac{4 \cdot h_0}{\cos\beta} = 16{,}25\ mm$$

We observe that: $S_0 = 16{,}25\ mm > d + d_s = 7{,}55\ mm$ so the grain cross the screen juming aproximately, from two in two holrs.

The angle of down fall of the grain in plane of the screen [3]: $\varepsilon = arctg(tg\alpha + tg\beta) - \beta = 23^\circ$

To value of the angle, the probability of passing through the screen of the ″difficult″ grains is reduced, it is favoured the passing of little grains becuse of their knocking to wires of holes. The revolution of crank, rezult:

$$n = \frac{30}{\pi} \cdot \sqrt{C_a \cdot \frac{g}{r} \cdot \frac{\cos\beta}{\sin(\alpha + \beta)}} = 822\ \ rot/min$$

The angular speed value of the vibrator for which the ″difficult″ grains unblock the holes of green passing in following holes is:

$$\omega \geq \sqrt{g \cdot \frac{d + d_s}{r^2} \cdot \frac{C_a^2}{C_a^2 - 1} \cdot \frac{\cos\beta}{\sin\gamma \cdot \cos\alpha}} = 84\ \ s^{-1}$$

to which correspond the revolution:

$$n = \frac{30}{\pi} \cdot \omega = 800\ \ rot/min\ .$$

We observe that the vibrator revolution determined by the coefficient of throwing ($n = 822\ \ rot/min$) assure removing of ″difficult″ grains from the screen holes.

The period of screen oscillation:

$$T = \frac{2 \cdot \pi}{\omega} = \frac{60}{n} = 0{,}073 \quad s$$

The average speed of advance of refuse in length of screen (is determined from the reason that to each oscillation of the screen, the material advance in length of this with distance S_0): $v_m = \frac{S_0}{T} = 0{,}22 \quad m/s$.

Knowing the value of average speed and the detail in refuse of screen, we can realize the technolgic dimension of this.

Let's consider the function work of the screen with sliding of the material down on the sieve. Considering the friction coefficient of the material on the screen $\mu = 0{,}5$, rezult the friction angle $\varphi = arctg0{,}5 = 27^0$.

The necessary revolution of the action work is:

$$n \geq \frac{30}{\pi} \cdot \sqrt{\frac{g}{r} \cdot \frac{\sin(\varphi - \beta)}{\cos(\varphi - \gamma)}} = 230\ \ rot/min\ ,$$

the angular speed: $\omega = \frac{\pi \cdot n}{30} = 24\ \ s^{-1}$.

For the work with shifting up on screen, the action revolution has the value:

$$n \geq \frac{30}{\pi} \cdot \sqrt{\frac{g}{r} \cdot \frac{\sin(\varphi + \beta)}{\cos(\varphi + \gamma)}} = 478\ rot/min\ .$$

For the working mechanism of the screen we adopt the revolution $n = 400\ rot/min$ ($\omega = 42\ s^{-1}$) to assure a convenient value of through-put capacity.
Considering that „difficult” grains have the dimention $d_p = 1{,}15 \cdot d$, from the table 1 or figure 4, rezult $\theta = 60^0$. The dinamic coefficient of the screen is:

$$K_d = \frac{r \cdot \omega^2}{g} = 0{,}9 .$$

The blocking coefficient of holes has the values: $k_b = tg(\theta - \beta) = 1{,}19$.
The condition that grains don't block the screen holes, $K_d \geq tg(\theta - \beta)$, is not fulfil.
From the condition:
$k_b = tg(\theta - 10^0) = K_d = 0{,}9$ result: $\theta = 52^0$.
For this value of angle θ, from the table 1 or figure 4 result $d_p/d = 1{,}27$. Consequently, to function in these coditions of the screen, only grains with $d_p \geq 1{,}27 \cdot d = 8{,}0\ mm$ will not block the screen holes.
If the screen is horizontal, the others functional characteristics of the screen preserved, result alternatively: $k_b = tg\theta = K_d = 0{,}9$; $\theta = 42^0$; $d_p/d = 1{,}46$. Then, for work the screen in these condition, only grains with $d_p \geq 1{,}46 \cdot d = 9{,}2\ mm$ will not block the screen holes.
We can observe that the inclination of the screen face to horizontal, reduce the tendecy of grains to obturate the screen holes.
It is recomend, when the technological conditions allow, the function of screen in conditions of jump grains on screen which is advantageous regarding avoidance of blocking screen with „difficult” grains.

6. CONCLUSIONS

The sieving process is influenced both by the friction between material and screen and by the obturation of the holes of screen by blocking the grains. The friction influence especially shifting by sliding of the material on the screen.
While the sifting, some grains, depending on comparison between their dimensions and that of screen holes, fixed in these hending the screen and, consequently, perturbing the process.
As much the dimension of grains is more appropriate to that of the holes („difficult” grains), so much the phenomenon of fixing of grains in screen holes is stronger, necessitating, to unblock that, bigger acceleration of screen. The phenomenon of blocking holes of screen is diminished in proportion with increase the inclination of screen in front of horizontal plane.
When the technological conditions allow, we prefer the work of screen in condition of jump of the grains on screen, which is advantageous, between others, also from point of view of avoidance of screen bottom up with „difficult” grains.

BIBLIOGRAPHY

[1] V. V. Jinescu, Utilaj tehnologic pentru industrii de proces, vol. IV, Editura Tehnică, Bucureşti, 1989.
[2] V. V. Jinescu, Maşini cu elemente elicoidale, vol. I, Editura AGIR, Bucureşti, 2007.
[3] Gh. Ene, Echipamente pentru clasarea şi sortarea materialelor solide polidisperse, Editura Matrix-Rom, ISBN 973–685–911–8, Bucureşti, 2005.
[4] Gh.Ene, Determinarea coeficientului de frecare dintre materialele granulare şi sitele din ţesătură, Revista de Construcţii, 1995, p. 43-47.
[5] Gh. Ene, Studiu privind mişcarea cu salturi a materialului pe sita ciururilor oscilante, Revista de Chimie, 52, nr. 7- 8, 2001, p. 420 - 425.
[6] *** Manualul inginerului din industria cimentului, Vol. I, Editura Tehnică, Bucureşti, 1994.
[7] Iatan R., Consideraţii teoretice cu privire la ciuruirea prin alunecare pe sitele din tablă cu ochiuri circulare şi pătrate, Revista de chimie, 24, nr. 2, 1973, p. 125 – 130.
[8] M.Munteanu, R.Iatan, Gh. Ene, Dinamica maşinilor vibratoare de tip pendul sferic inversat, cu mişcare de balans, în Revista de chimie, 36, nr.11, 1985, p. 1043-1049
[9] Gh. Ene, R.Iatan, Dinamica ciururilor cu mişcare de ruliu, în Revista de chimie, 39, nr.3, 1988, p. 279-282.