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

I. THE DETERMINATION OF FUNCTIONAL CHARACTERISTIC OF THE SCREEN

We consider a screen with siev inclined with angle \( \beta \) against horizontal, realize vibrations after linear trajectory which form the throwing angle \( \gamma \) with direction of the screen (angle \( \alpha \) 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.

\[
F_1 \cdot \cos \gamma - m \cdot g \cdot \sin \beta \geq F_f
\]

Taking consideration that the inertia force has the expression:

\[
F_f = m \cdot r \cdot \omega^2
\]

and friction force:

\[
F_f = m \left( g \cdot \cos \beta + r \cdot \omega^2 \cdot \sin \gamma \right) \tan \phi
\]

from relation (2) we obtain:

\[
K_d = \frac{r \cdot \omega^2}{g} \geq \frac{\sin(\omega + \beta)}{\cos(\omega + \gamma)}
\]

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

\[
n \geq \frac{30}{\pi} \sqrt{\frac{g \cdot \sin(\omega + \beta)}{r \cdot \cos(\omega + \gamma)}} \text{ rot / min (5)}
\]

\((r \text{ is expressed in m, and } g \text{ in } m / s^2).\)

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.

\[
F_1 \sin \gamma = mg \cos \beta + mg \sin \gamma + F_i \sin \gamma
\]

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

\[
K_d = \frac{r \cdot \omega^2}{g} \geq \frac{\cos(\omega - \gamma)}{\sin(\omega - \beta)}
\]

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

\[
n \geq \frac{30}{\pi} \sqrt{\frac{g \cdot \sin(\omega - \beta)}{r \cdot \cos(\omega - \gamma)}} \text{ rot / min (7)}
\]

To impede 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:

\[
N = m \left( g \cdot \cos \beta - r \cdot \omega^2 \cdot \sin \gamma \right)
\]

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

\[
g \cdot \cos \beta - r \cdot \omega^2 \cdot \sin \gamma = 0
\]

The condition (6) may be as forms:
If we observe that \([3, 5]\):

\[
v = r \cdot \omega \cdot \sqrt{\frac{l - l}{C_a}}
\]

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

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

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

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

in which \(\gamma = \alpha + \beta\) represent the throwing angle.

Considering the expressions (12) and (16), the condition (15) become:

\[
h_0 = r \cdot \frac{C_a^2 - 1}{C_a} \cdot \cos \alpha \geq d + d_s
\]

The correlation (30) permit the determination of angle \(\alpha\):

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

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

\[
S_0 = 2 \cdot v_h \cdot \frac{\sin \gamma}{g} \cdot \frac{\sin \gamma \cdot \cos \alpha \cdot \cos^2 \beta}{d + d_s}
\]

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 :

\[
S_0 = \frac{4 \cdot h_0}{\cos \beta}
\]

The dimension of the angle \(\beta\) is adopted constructive observing the following specifications.

The screen is put in horizontal plane or inclined with an angle \(\beta\) face to this. The angle \(\beta\) 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 \(\beta\) 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 \([3, 5]\).
The coefficient of throwing is essential dimension for the correct functional for screen. The practical experience recommend for oscillating screen the following values of the throwing coefficient [3, 5]:

- $C_a = 1.3...1.6$ – for friable materials (which can by break during the screening);
- $C_a = 1.7...2.0$ – for materials which are not breaking during the screening;
- $C_a = 2.0...2.4$ – for sticky materials, which 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:

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

and revolution with relation:

$$n = \frac{30}{\pi} \sqrt{\frac{C_a \cdot \frac{g}{r} \cdot \frac{\cos \beta}{\sin \gamma}}{m^{-1}}} \text{, rev/min}$$  \hspace{1cm} (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 gran ion the 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 $\alpha$:

$$\alpha = \arccos \left( \frac{d + d_s}{r} \frac{C_a}{C_a^2 - 1} \right) = 30^\circ$$

We adopt the value $\alpha = 25^\circ$.

For angle $\beta$ we adopt $\beta = 10^\circ$.

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

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

It is executed the condition:

$$h_0 = 4 \text{ mm} > \frac{d + d_s}{2} = 3.7 \text{ mm}$$

The length of grain jump on screen:

$$S_0 = \frac{4 \cdot h_0}{\cos \beta} = 16.25 \text{ mm}$$

We observe that: $S_0 = 16.25 \text{ mm} > d + d_s = 7.55 \text{ mm}$. so the grain cross the screen juming approximately, from two in two holes.

The angle of down fall of the grain in plane of the screen [3]:

$$\epsilon = \arctan(g \alpha + tg \beta) - \beta = 23^\circ$$

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 because of their knocking to wires of holes. The revolution of crank, result:

$$n = \frac{30}{\pi} \sqrt{\frac{C_a \cdot \frac{g}{r} \cdot \frac{\cos \beta}{\sin(\alpha + \beta)}}{m^{-1}}} = 822 \text{ rev/min}$$

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

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

to which correspond the revolution:

$$n = \frac{30}{\pi} \omega = 800 \text{ rot/min}.$$  \hspace{1cm} (25)

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

The period of screen oscillation:

$$T = \frac{2 \cdot \pi \cdot \omega}{\omega} = 0.073 \text{ s}.$$  \hspace{1cm} (26)

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 $S_0$): $v_m = \frac{S_0}{T} = 0.22 \text{ m/s}.$

Knowing the value of average speed and the detail in refuse of screen, we can realize the technologic 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 $\mu = 0.5$, result the friction angle $\varphi = \arctg 0.5 = 27^\circ$.

The necessary revolution of the action work is:

$$n \geq \frac{30}{\pi} \sqrt{\frac{g \cdot \sin(\varphi - \beta)}{r \cdot \cos(\varphi - \gamma)}} = 230 \text{ rot/min}.$$  \hspace{1cm} (27)

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

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

$$n \geq \frac{30}{\pi} \sqrt{\frac{g \cdot \sin(\varphi + \beta)}{r \cdot \cos(\varphi + \gamma)}} = 478 \text{ rot/min}.$$  \hspace{1cm} (28)

<table>
<thead>
<tr>
<th>Dimensions of holes, mm</th>
<th>6</th>
<th>12</th>
<th>22</th>
<th>45</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplitude oscillation, A = r, mm</td>
<td>5</td>
<td>7.5</td>
<td>10</td>
<td>12.5</td>
<td>20</td>
</tr>
<tr>
<td>Revolution of crank, rot / min</td>
<td>800</td>
<td>710</td>
<td>700</td>
<td>690</td>
<td>620</td>
</tr>
</tbody>
</table>

Table 2. Values of parameters of oscillation.
For the working mechanism of the screen we adopt the revolution \( n = 400 \text{ rot/min} (\omega = 42 \text{ s}^{-1}) \) to assure a convenient value of through-put capacity. Considering that „difficult“ grains have the dimension \( d_p = 1.15 \cdot d \), from the table 1 or figure 4, result \( \theta = 60^\circ \). The dynamic coefficient of the screen is: \[ K_d = \frac{r \cdot \omega^2}{g} = 0.9. \]

The blocking coefficient of holes has the values: \( k_b = \tan(\theta - \beta) = 1.19 \).

The condition that grains don’t block the screen holes, \( K_d \geq \tan(\theta - \beta) \), is not fulfil.

From the condition:
\[ k_b = \tan(\theta - 10^\circ) = K_d = 0.9 \]
result: \( \theta = 52^\circ \).

For this value of angle \( \theta \), from the table 1 or figure 4 result \( d_p/d = 1.27 \). Consequently, to function in these conditions of the screen, only grains with \( d_p \geq 1.27 \cdot d = 8.0 \text{ mm} \) will not block the screen holes.

If the screen is horizontal, the others functional characteristics of the screen preserved, result alternatively: \( k_b = \tan \theta = K_d = 0.9 \); \( \theta = 42^\circ \); \( d_p/d = 1.46 \). Then, for work the screen in these condition, only grains with \( d_p \geq 1.46 \cdot d = 9.2 \text{ mm} \) 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.

### BIBLIOGRAPHY