Determination of the Optimal Productivity of a Screw Conveyor Vacuum-Press for Molding Ceramic Green Mixes

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The determination of the optimal productivity of a screw conveyor vacuum-press molding articles from ceramic green mixes is analyzed. Different variants of productivity determination taking account of the motion of porcelain mix in the press channels and its physical – mechanical properties are presented.

Key words: ceramic, production, green mix, vacuum-press, productivity, calculation.

Green mix becomes enriched with air during fine milling of stony and softening of clayey materials in the production of ceramics. The presence of air degrades the molding properties of the mix and affects press productivity, so that it becomes necessary to pre-degas the mix in a screw conveyor vacuum-press. The productivity of a screw conveyor vacuum-press depends on a number of factors: its geometric parameters, the physical – mechanical properties of the ceramic green mix being molded, the rotation rate of the screw, the shape of the articles being molded, the specific pressing pressure, the initial (nominal) gap between the expressing blade of the screw and the cylinder lining jackets, and so on.

Until now the large number of interfering factors and the lack of theoretical relations for some of them have made it impossible to develop a unified method for determining theoretically the productivity of a screw conveyor vacuum-press, which is very important to do for production.

The SNK-325 press is used in domestic and foreign press-construction practice. This press is equipped with a mechanism for regulating the gap between the edge of a screw blade and the cylinder jacket; this has increased the productivity of the press [1].

The driver of a screw press can be calculated if the productivity is represented as the result of the interactions of three flows of the ceramic green mix in the working channels of such a press.

The translational motion of the ceramic green mix in the cylinder of the press arises as the result of its being pushed by the frontal surface of a screw blade. Over one turn of the screw the mix moves over a distance equal to the pitch of the screw (Fig. 1).

It is known from practice that when the edge of a screw blade and the cylinder jacket becomes worn ceramic mix flows under the pressure gradient through the blade edge in a direction opposite to the axial motion of the mix in the cylinder [2]. This so-called “leakage flow” will be all the greater, the larger the gap between the blade edge and the surface of the cylinder and the larger the pressure difference on both sides of the screw blade (Fig. 2).

Thus, the following basic mix flows are observed in the driver of the screw press during molding of the material:

- forward flow \( Q_{fw} \) produced by the pushing power of the frontal surface of the screw blades;
- backward flow \( Q_{bw} \) caused by the pressure from the side of the press head and the motion of the screw blade surfaces in the opposite direction (as a rule a backward flow in the di-

Fig. 1. Working channel of the forward flow of the green mix.
The leakage flow of the mix, depending on the pressure difference between the mix flows in the press channel.

rect sense does not exist; it is manifested in the checking influence on the forward flow \([1]\); leakage flow \(Q_{lk}\) caused by the pressure difference between both sides of a screw blade in the annular channel along the perimeter of a blade.

In general, taking account of all flows the productivity of a screw conveyor vacuum-press is described by the equation:

\[
Q = Q_{fw} - Q_{bw} - Q_{lk}.
\]

The value of these parameters can be written as follows. The forward flow:

\[
Q_{fw} = \frac{\pi (D^2 - d^2) \mu n}{4 \times 60}, \text{ m}^3 \cdot \text{sec}^{-1},
\]

where \(D\) is the diameter of the expressing blade, \(m\); \(d\) is the diameter of the shaft of the screw, \(m\); \(t\) is the pitch of the screw line of the screw, \(m\); \(n\) is the rotation speed of the screw shaft, \(\text{min}^{-1}\).

The backward flow:

\[
Q_{bw} = \frac{\pi (D + d) L \mu n}{60} + \frac{\psi}{(1 + \psi) \mu_1} \left( \frac{K_\delta P_{ax}}{S} \right)^q L 2h^{q+2},
\]

where \(L\) is the distance from the screw shaft to the cylinder jacket, \(m\); \(2h\) is the pitch of the screw line of the screw shaft, \(m\); \(\psi\) is the index of the mix flow, which is 0.1 – 0.3; \(\mu_1\) is the viscosity, \(\mu_1 = 0.05 – 0.15\ \text{MPa} \cdot \text{sec}\); \(q\) is the specific characteristic of the mix flow index; \(K_\delta\) is the lateral pressure coefficient; \(P_{ax}\) is the axial pressure of the mix, \(\text{Pa}\); \(S\) is the length of the screw channel in the cylindrical part of the press channel; and, \(l\) is the length of the action path of the axial pressure on the mix, \(m\).

The leakage flow:

\[
Q_{lk} = \frac{\pi R \rho^\delta}{60} \left( \frac{P_{ax}}{l} \right)^q \frac{\psi}{\mu_1^q (1 + \psi)} \frac{\pi R S^{q+2}}{1 + 2\psi},
\]

where \(R\) is the radius of a screw blade, \(m\), and \(\delta\) is the distance between a screw blade and the cylinder jacket, \(m\).

Substituting the values of the parameters \(Q_{fw}, Q_{bw},\) and \(Q_{lk}\) into Eq. (1), having first projected on the horizontal axis of the rates, of the flows of the ceramic green mix in the screw channels, we obtained the relation [1]

\[
Q = \frac{\pi (D^2 - d^2) \mu n}{240} - \frac{t}{2\pi R} \left[ \frac{\pi (D + d) L \mu n}{60} + \frac{\psi}{(1 + \psi) \mu_1^q} \left( \frac{K_\delta P_{ax}}{S \cos \beta} \right)^q L 2h^{q+2} \right] + \frac{\pi R \rho^\delta}{60} \left( \frac{P_{ax}}{l} \right)^q \frac{\psi}{\mu_1^q (1 + \psi) (1 + 2\psi)}^{q+2},
\]

where \(\cos \beta\) is the projection of the slope angle of a turn of the screw on the horizontal axis.

The Eq. (2) can be represented in the simplified form

\[
Q = \frac{KP}{\mu_e},
\]

where \(K\) is the coefficient of the geometric shape of the head and the mouthpiece, called the “characteristic” of the shaping unit of the press; \(P\) is the pressure expended on overcoming the resistances in the channel; \(\mu_e\) is the effective viscosity; \(\mu_e = f(\gamma)\), where \(\gamma\) is the gradient of the velocity.

The Oswald – de Ville equation is most suitable for a mathematical description of this relation:

\[
\mu_e = \mu_1 (\gamma)^{q+1}
\]

or after taking the logarithm

\[
\log \mu_e = (\psi - 1) \log \gamma + \log \mu_1,
\]

where \(\mu_1\) is the viscosity with velocity gradient \(\gamma = 1\).

The Eq. (3) describes the behavior of the plastic ceramic green mix in a simple mathematical form.

The productivity \((Q, \text{m}^3/\text{sec})\) of a screw vacuum-press can be determined using a somewhat more accessible relation [3]:

\[
Q = \pi n \left( \frac{D^2 - d^2}{4} \right) (t - e) (1 - \alpha) k_1 k_2 k_3 k_4,
\]

where \(e\) is the thickness of a screw blade, \(m\); \(\alpha\) is the packing factor of the molded green mix; \(k_1\) is the productivity loss factor due to the return of the mix in the gap between the screw blades and the cylinder jacket of the screw; \(k_2\) is the influence factor for the lift angle of the median screw line of the screw; the factor \(k_3\) takes account of the number of returns of the expressing blade of the screw; and, the factor \(k_4\) takes account of the slipping of the mix along a screw blade.

If only simple calculations of the productivity of a specific press with definite parameters for concrete conditions (with known physical – mechanical parameters of the