NONSTATIONARY FLOW OF A GRANULAR MATERIAL FROM A GRAVITATIONAL HANDLER

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Studies have been made on the flow mechanism for a granular medium and have defined the velocity pattern in nonstationary flow during the development of a plastic zone in a rigid-plastic body. Studies have been made on the flow of a granular medium with and without internal friction. There are various stages in the growth of the plastic zone in a mixed powder composite with coefficient of friction 0.71.

Quality parameters, such as the throughput and reliability, are important under conditions of composition in the market for technological plant, in particular presses. However, any direct increase in the throughput tends to reduce the reliability parameters, which is due to the rate at which the processes occur and the physicomechanical properties of the material change. For example, a high-throughput bladed handler for volume dispensing in rotor-type tableting machines cannot be used in dispensing mixed powdery composites [1] on account of the elevated sensitivity to mechanical factors. Also, vibrational handlers lead to layering in the compositions in terms of the components. Therefore, such materials are dispensed in automatic systems by means of gravitational handlers, which provide the mildest conditions for processing granular materials. However, the dispensing of doses that are quite small by comparison with the volume of the feed bunker leads to operation in a mode of switching between emission and absence of emission. The flow processes in such a case are nonstationary, since the flow does not have time to propagate to the entire volume of material. We lack methods of calculating the flow of such materials under nonstationary conditions, so it is not practicable to design effectively such dispensing equipment for automatic presses.

In general, such nonstationary flow of such a medium is described by a system of quasilinear differential equations. The equation system is as follows for a planar moving granular medium that contains five unknown functions: three components of the stress tensor \( \sigma_x(x, y, t) \), \( \sigma_y(x, y, t) \), \( \tau_{xy}(x, y, t) \) and two components of the velocity vector \( v_x(x, y, t) \), \( v_y(x, y, t) \) which are dependent on the three independent variables \( x \), \( y \), and \( t \). It is difficult to solve such a system, so usually one considers only the steady-state motion [2, 3]. To construct the velocity pattern for nonstationary flow, it is convenient to use the turning-point principles in the theory of ideal plasticity [4, 5].

The essence of this method is that the supposed plastic region is dissected into rigid homogeneous blocks, which coincide one relative to another by overcoming the shearing resistance \( \tau_0 \). The problem is solved with the minimum acceptable hole, with possible flow, which allows one to determine the width of the minimum outlet hole.

I have considered the flow mechanism and the determination of the velocity pattern for nonstationary flow during the development of a plastic zone in a rigid-plastic body.

Flow of a Granular Medium Neglecting Internal Friction

Figure 1a shows a possible flow mechanism at the start of the opening of the outlet hole, which is dependent on the three parameters \( \alpha \), \( \beta \), and \( h_1/a \), which define the geometry of the flow zone.
The flow occurs in the zone $OBCO'C'B'$. Outside it, the material remains in a state of rest. We assume that the pressure on the line $CO'C'$ is zero, since the region lying above that line is in a state of rest, while on the line $BB'$ there acts the pressure $p_{BB'}$.

The motion of the blocks in the plastic zone $F_i$ determines the energy dissipation rate and the flow speed of the material $v_2$ (Fig. 1b) in the outlet hole [5].

The energy conservation equation takes the form

$$\rho g (\sum_{i=1}^{4} v_i L_i + 2 \sum_{i=1}^{4} v_i v_i F_i) = p_{BB'} v_2 + 2 \tau_0 (v_{AC} AC + v_i BC + v_{AB} AB + v_{O'C'O'C} C),$$

(1)

where $\rho$ is the poured density, and $g$ the acceleration due to gravity.

Plastic flow begins for $p_{BB'} = 0$, so the power balance equation may be written as

$$\frac{\rho g}{\tau_0} = 2 \sum_{i=1}^{4} v_i L_i / \sum_{i=1}^{4} v_i v_i F_i,$$

where $L$ is the distance between the plastic zones (blocks);

$$\sum_{i=1}^{4} v_i L_i = v_{AC} AC + v_i BC + v_{AB} AB + v_{O'C'O'C} = v_1 a \left[ \frac{v_{AC} AC}{v_i a} + \frac{BC}{v_i a} + \frac{v_{AB} AB}{v_i a} + \frac{v_{O'C'O'C}}{v_i a} \right];$$

$$\sum_{i=1}^{4} v_i v_i F_i = v_0 F_{CAC'O'} + 2 v_1 v_i F_{ABC} + v_2 F_{ABB'} = v_1 a^2 \left[ \frac{v_0 F_{CAC'O'}}{v_1 a^2} + 2 \frac{v_1 v_i F_{ABC}}{v_1 a^2} + \frac{v_2 F_{ABB'}}{v_1 a^2} \right],$$

in which $a$ is the parameter of the outlet hole.

Transformation gives

$$f \left( \alpha, \beta, \frac{h_1}{a} \right) = \frac{\rho g a}{\tau_0} = \frac{v_{AC} AC + BC}{v_i a} + \frac{v_{AB} AB}{v_i a} + \frac{v_{O'C'O'C}}{v_i a} \right] + \frac{v_0 F_{CAC'O'}}{2 v_1 a^2} + \frac{v_1 v_i F_{ABC}}{2 v_1 a^2} + \frac{v_2 F_{ABB'}}{2 v_1 a^2}.$$

(2)

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