EFFECT OF GAS FLOW FILTRATION UPON LOOSE MATERIAL FORCED DISPLACEMENT PROCESSES IN PIPES

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Theoretical and experimental confirmation is obtained for a relation between the stress in loose material beds forced through a vertical pipeline and the gas flow filtration velocity in such beds.

Transportation of dry loose material forced through vertical or inclined pipes by mechanical stimulators is only possible for small heights of the displaced material beds, since an increase in the bed height would create significant increases in thrust forces acting on the pipeline walls [1, 2].

Gas blown through a bed of loose material forced upward by a piston along a vertical pipe can substantially influence resistance values. The magnitude of the effect upon resistances for a given material column will depend mainly on the gas flow filtration velocity through the bed [3].

Let us find the relation between the stresses in a displaced material bed and the gas flow filtration velocity. A one-dimensional model of loose material will be considered. Such a model proved to be quite satisfactory in previous studies [1, 4] for the representation of loose material displacement processes without aeration. We can assume that the effect of the gas flow during displacement of an aerated bed can be expressed in terms of weight reduction of particles composing this bed due to changes in hydraulic resistances. The differential equation for vertical components of forces acting upon a selected elementary volume of a bed having an infinitesimal thickness dh (Fig. 1) taken from a section of a vertical pipe, along which a piston forces a column of loose material upward, can be expressed as

$$\frac{\pi D^2}{4}\left(\gamma_v - \frac{dP}{dh}\right) dh + \frac{\pi D^2}{4}\ \sigma = (\sigma + d\sigma)\ \frac{\pi D^2}{4} - \sigma_б f \pi D dh. \tag{1}$$

Let us represent the ratio of lateral to vertical pressures as a lateral pressure coefficient

$$n = \frac{\sigma_b}{\sigma}.$$

Solving Eq. (1) we obtain an equation for determination of stresses in the displaced material as a function of the bed relative height and the gas flow filtration velocity:

$$\sigma_b = \frac{D}{4f}\left(\gamma_v - \frac{dP}{dh}\right)\left(e^{4fn\frac{h}{D}} - 1\right). \tag{2}$$

The pressure gradient dP/dh is dependent on the velocity of the gas filtering through the bed. When this velocity equals zero (no gas blown through),

$$\frac{dP}{dh} = 0$$

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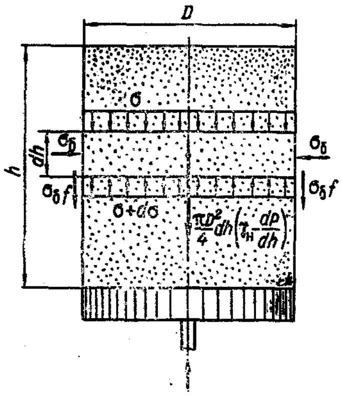

Fig. 1

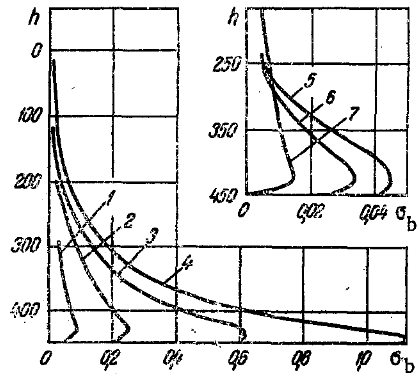

Fig. 2

Fig. 1. Schematic diagram of the displacement of aerated loose material by a piston.

Fig. 2. Experimental curves on lateral pressure plotted against medium grain bed height for different relative air flow filtration velocities: 1) $\omega/\omega_{cr} = 0$; 2) 0.27; 3) 0.38; 4) 0.51; 5) 0.75; 6) 0.9; 7) $\omega/\omega_{cr} = 1$. h, mm; σ_b, kgf/cm^2.

and so Eq. (2) becomes identical to the equation obtained by Zenkov [1]. The pressure gradient increases with rising gas filtration velocity and, other conditions being equal, this leads to a decrease in lateral pressure. When the filtration velocity reaches a value at which the aerated bed enters a quasiliquid state,

$$\gamma_v - \frac{dP}{dh} = 0$$

the material acquires viscous characteristics and becomes in this respect similar to a liquid.

The above discussion on the relation between stresses in a forcibly displaced loose material and gas flow filtration velocity were checked by experiments conducted on different materials. As an example, results obtained on one of the grain grinding products, namely, on medium grain samples, are presented.

Lateral pressure distribution along the material's bed height is shown in Fig. 2 for different values of relative gas flow filtration velocity ω/ω_{cr}. The lateral pressure diagrams were obtained experimentally for a relative column height of h/D = 5. The lateral pressure coefficients were within ranges of n = 0.25–0.45 at relative filtration velocities $\omega/\omega_{cr} = 0$–0.75. At relative filtration velocities $\omega/\omega_{cr} > 0.75$ a sharp increase in values for lateral pressure coefficients from 0.45 to 1.0 was observed. It can be clearly seen from this figure that with an increase in air flow filtration velocity through a bed of material forced through a pipe, the lateral pressure decreases, and when the air flow velocity becomes ω_{cr}, loose materials become similar to a liquid, as illustrated in the diagram for lateral pressures on pipeline walls (see Fig. 2, curve 7).

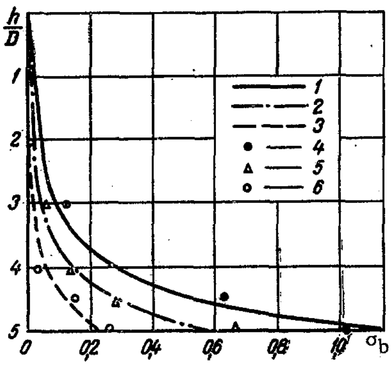

Fig. 3. Comparison of results obtained by computation and experimental data for medium grain beds on lateral pressure as a function of the relative height of the bed at different gas flow filtration velocities. Calculated values: 1) $\omega/\omega_{cr} = 0$; 2) 0.27; 3) 0.38. Experimental data: 4) at $\omega/\omega_{cr} = 0$; 5) 0.27; 6) 0.38.

Comparison of experimental data for maximal lateral pressures obtained for beds of various relative height with results obtained by computation using Eq. (2) indicated insignificant discrepancies (Fig. 3). Therefore, it is possible to recommend the application of the above expression for calculations on stresses in aerated loose material beds during their forced motion along vertical pipes.

NOTATION

D, diameter of the pipeline; f, resistance coefficient; h, loose material bed height above the piston; n, lateral pressure coefficient; σ, vertical pressure; σ_b, loose material pressure on pipeline walls; ω, gas flow filtration velocity through the loose material bed; ω_{cr}, gas flow filtration velocity at which the fluidization effect for a given material begins; dP/dh, pressure gradient due to gas flow filtration through the loose material bed; γ_v volumetric weight of loose material.

LITERATURE CITED

1. R. L. Zenkov, Mechanics of Bulk Cargo [in Russian], Mashinostroenie, Moscow (1964).
2. A. G. Frolov, Fundamentals of Loose Material Transportation along Pipes without Carrier Fluids [in Russian], Nauka, Moscow (1966).
3. P. N. Platonov, F. A. Fedorov, and V. N. Konshin, Reference Information on Completed Research Projects in Higher Educational Institutes of the Ukrainian SSR [in Russian] No. 9, Kiev (1974).
4. M. É. Aérov and O. M. Todes, Hydraulic and Thermal Operating Principles of Apparatuses with Stationary and Boiling Granular Beds [in Russian], Khimiya, Moscow (1968).

PRESSURE LOSS DURING FLUID FLOW IN A CHANNEL ROTATING PERPENDICULARLY TO THE AXIS OF ROTATION

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Results are presented which were obtained in experiments to determine the hydraulic resistance of a channel during its rotation around an axis perpendicular to the channel axis.

In the design of cooling systems for rotating objects, one needs data on the hydraulic resistance of channels whose axes are perpendicular to the axis of rotation. Studies that have been made [1, 2, 3] gave good agreement of results only for low rates of rotation where Coriolis forces have a controlling effect on flow [4].

At high rates of rotation, i.e., in the region where centrifugal forces have a controlling influence, considerable disagreement is observed in the data from available experimental studies [2, 5, 6]. Because of this, the performance of further experiments is advisable.

This paper presents the results of a study of pressure loss in a straight, technically smooth channel of circular cross section which is arranged perpendicularly to the axis of rotation, being a section of a rectangularly shaped rotating system, and which is included in a circulation loop. To perform the experiments, a special device was constructed with rotational speeds up to 1000 rpm having a 130-mm mean radius of channel rotation and a hydraulic system which provided the required flow rates and pressures of the working medium (water and transformer oil were used in the experiments).

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