THEORY OF FILTRATION OF NON-NEWTONIAN LIQUIDS THROUGH POROUS MEDIA

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The flow of abnormally viscous liquids through screens with pores of rectangular cross section is examined.

In view of the increasing production of polymeric materials the development of methods of calculating technological processes is becoming of very great importance. The derivation of equations for the calculation of technological processes used in the production of polymeric materials from solutions and melts requires a consideration of the rheological properties of polymer solutions and melts as well as the kinetics and design parameters.

In the present paper we consider the filtration of abnormally viscous liquids through porous media. There is a complex interrelationship between the three main factors affecting filtration – the kinetics, the structure of the filter material, and the rheological properties of the polymer solutions. As the solutions become purified the shape of the cross section of the pores in the filter screen changes. This must be taken into account in the derivation of the initial equation for the flow velocity through a single pore.

We consider the filtration of abnormally viscous liquids through screens with pores of rectangular cross section. This class of filter materials includes cloths and metal grids, which can be regarded as diaphragms with a monodisperse pore space [1, 2]. Filter cloths are woven materials (linen, serge, satin) and their open pores are square or rectangular. Figure 1 shows an element of a filter cloth and its main geometrical parameters.

In a hypothetical soil with rhombus angle $\theta > 60°$ the channels have a four-sided cross section whose sides are arcs of a circle. If we assume the presence of stagnant zones, the problem in a first approximation can be reduced to the solution of the problem of flow through a channel of rectangular (square) cross section (Fig. 2).

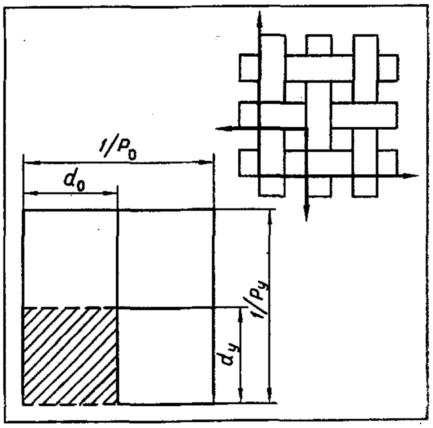

Fig. 1. Element of filter cloth.

We consider the derivation of the equation for filtration of an abnormally viscous liquid through a channel of rectangular cross section (Fig. 3). For a steady flow of incompressible, abnormally viscous liquid the equation of the mean velocity for any cross section has the form [3]

$$V = \sum K \iint_s \left[\left(\frac{\partial \Phi}{\partial x}\right)^2 + \left(\frac{\partial \Phi}{\partial y}\right)^2\right]^{\frac{m}{2}+1} dydx, \tag{1}$$

where $K = f(\alpha, m, \Delta p, \eta_0, R, a, b)$; α, m, and η_0 are the rheological parameters of the solution; R, a, and b are geometric dimensions of the filter material. The function $\Phi(x, y)$ for this case is given by the relationship

$$\Phi = [\alpha_0 + \alpha_1 (x^2 + y^2)] (x^2 - a^2) (y^2 - b^2), \tag{2}$$

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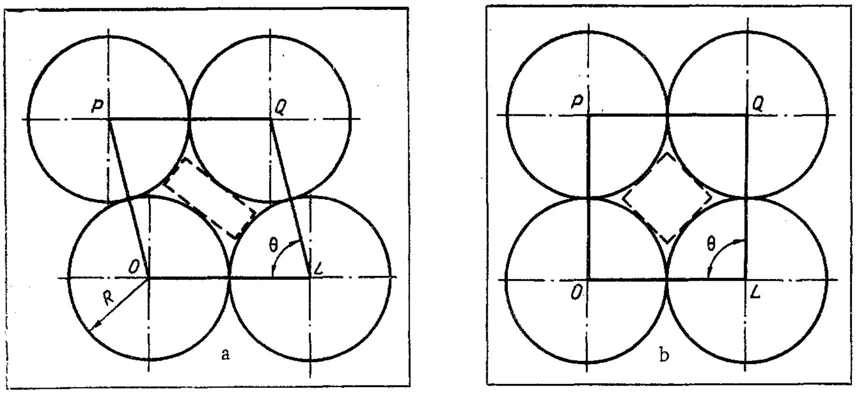

Fig. 2. Cross section of hypothetical soil: a) $60° < \theta < 90°$; b) $\theta = 90°$.

where

$$\alpha_0 = \frac{5}{4} \cdot \frac{259}{277\,(a^2 + b^2)}\,;$$
$$\alpha_1 = \frac{15}{4} \cdot \frac{35}{277} \cdot \frac{1}{(a^4 + b^4)}\,. \tag{3}$$

Substituting the values of $\partial\Phi/\partial x$, and $\partial\Phi/\partial y$ in (1) we obtain the following integral expression for the first approximation:

$$\alpha_1 = 0; \quad \alpha_0 = \frac{5}{4} \cdot \frac{1}{(a^2 + b^2)}\,;$$
$$I = A \int_{-1}^{1} \int_{-1}^{1} [\bar{x}^2 (\bar{y}^2 - 1) + c^2 \bar{y}^2 (\bar{x}^2 - 1)^2]^{\frac{m}{2}+1}\, dy dx, \tag{4}$$

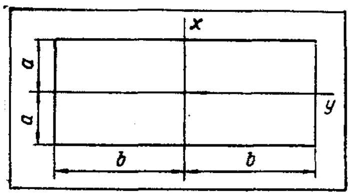

Fig. 3. Flow of abnormally viscous liquid through a channel of rectangular cross section.

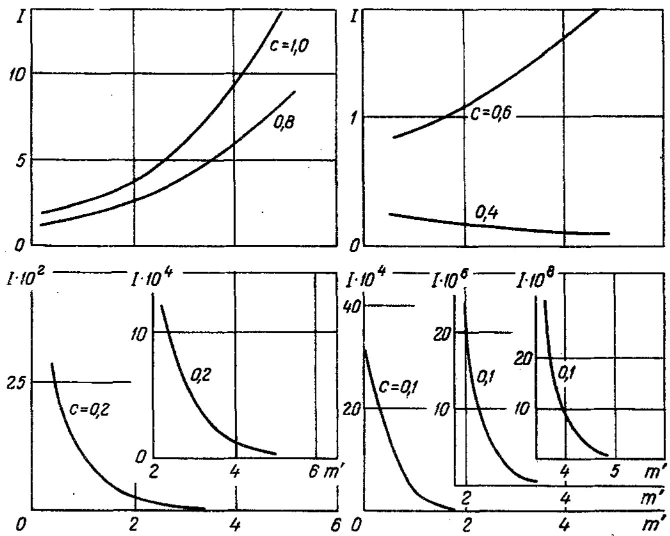

Fig. 4. Plots of I against rheological constant m'.

where

$$A = c \cdot \left[\frac{25}{4} \cdot \frac{c^2}{(c^2+1)^2} \right]^{\frac{m}{2}+1};$$

$$c = \frac{a}{b} (1.0;\ 0.8;\ 0.6;\ 0.4;\ 0.2;\ 0.1;\ 0.05).$$

The integral was solved on a M-20 computer for m' = m/2 = 0–48. Figure 4 shows plots of the integral I against the rheological characteristic m of the solution for various values of c. The change in the shape of the curve is due mainly to the change in the coefficient A with c.

Thus, the obtained data can be used to calculate filtration through porous media with pores of rectangular section.

LITERATURE CITED

1. V. A. Zhuzhikov, Filtration [in Russian], Khimiya, Moscow (1968).
2. I. V. Piskarev, Filter Cloths. Fabrication and Use [in Russian], Moscow (1963).
3. K. D. Vachagin, M. G. Saifullin, and G. V. Vinogradov, Inzh.-Fiz. Zh., 18, No. 6, 1970.