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CONCERNING THE MECHANISM OF "CHOKING" IN TUBE FLOWS OF DISPERSE SYSTEMS

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Electrokinetic phenomena in cohesive-discrete systems are considered. Based on the results of experimental investigations, a "choking" mechanism in the systems investigated is proposed.

Certain complex systems possess rheopectic properties that are responsible for the appearance of peculiar effects. The practical use of such systems in pipelines has confronted researchers with the problem of plugging. The point is that, when disperse systems are transported through pipelines, plugs are formed that clog the pipes [1-3]. Analysis of numerous works shows that this effect is observed irrespective of the spatial orientation of the pipes. "Suspended" or "cartridge" plugs are frequently encountered in practice [1].

The authors of [1] show that such systems are characterized by an angle of internal friction ρ and a coefficient of cohesion k that are characteristic of a cohesive-discrete medium exhibiting the "choking" effect.

The present article suggests a different mechanism for these phenomena.

A clay bentonite solution with density $\gamma = 1210$ kg/m^3 and a viscosity of 0.022 Pa·sec with added quartz sand particles with diameter $d < 0.001$ m in the amount of 30% of the solution volume was subjected to tests on the setup depicted in Fig. 1. The prepared cohesive-discrete system was placed in a vessel 3, which was connected to a compressed-air cylinder 1. The extrusion pressure in the system P was controlled by a microregulator 2. Transformer oil was placed over the system, so it could be extruded uniformly from the vessel. .

As the system was gradually loaded, the solution was forced out into glass tubes 8 and 9. As is seen from the figure, the solution moved from the top down in tube 9 and from the bottom upwards in tube 8. With further loading of the system, the descending motion of flow stopped, despite a further increase in pressure; but the ascending flow continued, though the reverse was to be expected. Throughout the entire time period and on cessation of the ascending flow, the system did not sink under gravity.

To reveal the mechanism of this effect, the electrokinetic properties of the above systems were investigated with allowance for the fact that a disperse system carries a surface charge [4, 5].

The tests were conducted on a setup (see Fig. 2) consisting of the following basic elements: U5-7 electric potentiometer 1, electrodes 2, a glass tube 3 with a diameter of 0.012 m and a length of 0.8 m with the investigated system 5, an air supply 4, and a cock 6.

The electrodes were placed at the inlet and outlet of the tube containing the disperse system. As part of the study, the potentials were recorded by connecting the upper inlet electrode to the background of the device; the lower electrode indicated the accumulation potential.

In the first series of experiments the motion of the dispersed phase from the top down was considered. In the vertical tube filled with the system the particles settled out onto the electrode located in the lower portion of the tube. In the second series of experiments the electric potential of the system in the ascending dispersed phase flow was recorded.

As seen from Fig. 3, the electric potential in the descending system is higher than that for the ascending flow. The results obtained allow an assumption about the mechanism involved in the choking effect. Since the particles interact with one another and have a certain surface charge of the same sign [5], this could lead to the repulsion of solid particles from one another, causing an "outward thrust" effect.

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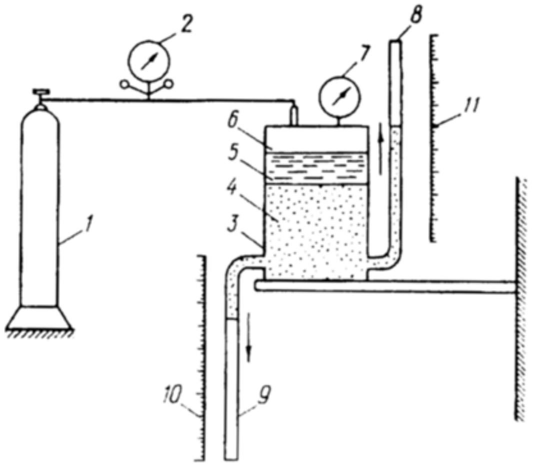


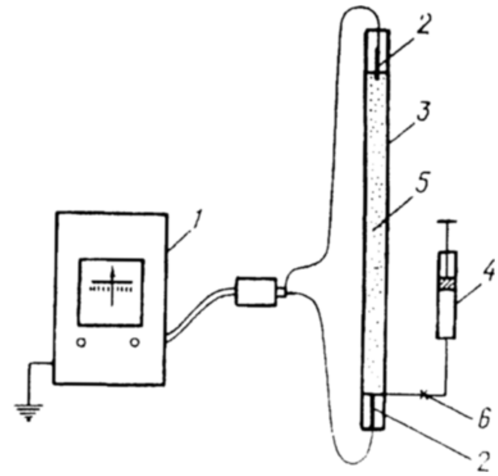
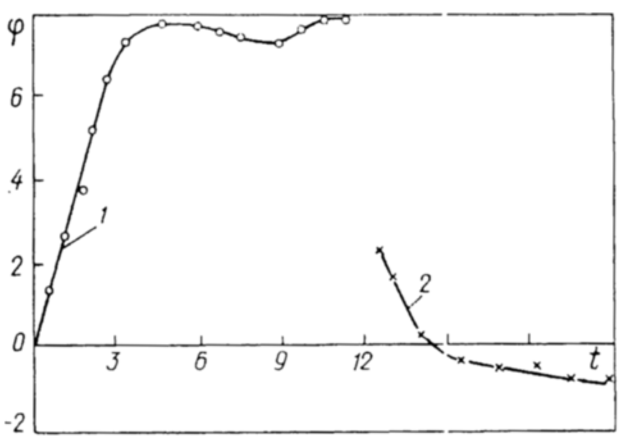


Fig. 1. Diagram of experimental setup: 1) compressed-air cylinder; 2) microregulator; 3) vessel; 4) system investigated; 5) transformer oil; 6) air space; 7) pressure gauge; 8, 9) glass tubes; 10, 11) measuring rules.

Fig. 2. Diagram of experimental setup: 1) device for measuring potential; 2) electrodes; 3) tube; 4) air supply; 5) medium investigated; 6) cock.



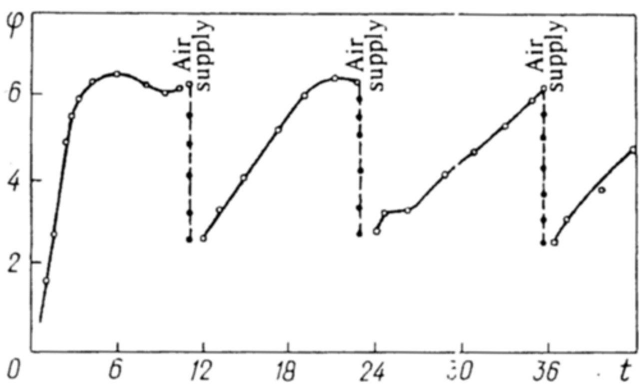


Fig. 3. Variation in time of the electric potential: 1) ascending flow; 2) descending flow. φ, mV; $t/600$ sec.

Fig. 4. Variation in time of the electric potential after air injection.

In the third series of experiments the possibility of controlling the electric potential was considered. For this purpose, a cyclic injection of 10^{-6} m^3 air from the source was performed (Fig. 2). The results showed that the magnitude of the charge accumulated decreases sharply after air injection and then gradually recovers (see Fig. 4).

Based on the investigations carried out, the following conclusions can be made:

1. Particles of quartz sand entering into a clay solution carry the charges of the natural field.

2. The choking effect in the motion of such cohesive-discrete systems as a clay solution with the addition of quartz sand is caused by the surface electric charge.

3. It is established experimentally that the plugging of pipelines can be prevented by using gas inclusions.

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NOTATION

ρ, angle of internal friction; k, coefficient of cohesion; γ, density of fluid; φ, electric potential; t, time; P, extrusion pressure.

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