Research and development of waste waters vibroacoustic purification methods for mining enterprises

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Abstract

Purpose. Intensification of effluents treatment process and increase in the quality thereof due to use of vibroacoustic oscillations. Development of the technique and technology of vibroacoustic filtration.

Methods. We studied a physical mechanism of filtration process during application of elastic oscillations on the basis of research of hydrodynamic situation during filtration and behavior of suspended particles. Effectiveness and fineness of filtration were examined for various filter materials depending on the mode of oscillations.

Results. Parameters of waste waters filtration were found to improve under the effect of vibroacoustic oscillations. The performance and effectiveness of filtration do depend on characteristics of filtering material, the amplitude of oscillating velocity and frequency of oscillation. Methods of calculation of the optimal mode to conduct vibroacoustic filtration have been developed.

Scientific novelty. Under the effect of oscillations, hydrodynamic conditions of the filtration process change. There emerge counter-current and tangential fluid flows due to which regeneration of filter elements takes place. Conditions for appearance of such flows have been determined.

Practical utility. We have designed and developed a pilot of a vibroacoustic filter which has already passed verification in industrial conditions. Results of these tests have shown application perspectiveness of this method in water-sludge systems of mining enterprises.

Key words: purification, waste waters, vibroacoustic filter, counter-current flows, filter regeneration.

Task setting.

The issue of effluents purification from highly dispersed mechanical admixtures is rather critical for most of mine enterprises. Certainly one can treat waste waters to bring them to standard norms using filter materials. Nevertheless, these have one essential drawback: filter pores become clogged very quickly and the process performance sharply drops down.

We propose a cardinal solution to this problem with the help of vibroacoustic oscillations method. The innovative element of the proposal is purification of waste waters on filtering materials with simultaneous impact of vibroacoustic oscillations on the suspension. The gist of our proposal is to change the modes of suspension passing through a filter element due to the pulse-wave effect. As a result, continuous filter regeneration takes place and conditions of particles extraction from the suspension are improved. So, we can solve the critical task of waste waters purification from highly dispersed suspended solids.

Basics of the principle.

The intensifying effect of vibroacoustic oscillations on separation of multiple-phase suspensions is based on physical effects such as counter-current regeneration (restoration) of filter elements due to varying pressures and liquid flows, as well as to change in the velocity of suspended particles movement [1, 2]. The point is that at a certain moment the pressure behind the filter partition exceeds the pressure in front of the partition, leading to a «reverse» pressure difference [3, 4]. Under this effect, counter-current flows appear in the fluid the direction of which is counter to the main flow, the so called «counter-current» flows. Due to these flows, filter pores are cleaned and suspended particles on its surface are destroyed [5, 6]. After this, hydrodynamic characteristics of the grid partition are restored (the hydrodynamic resistance is reduced). The filter regeneration takes place with a frequency equal to oscillations frequency.

We studied conditions for emergence of such counter-current flows and dependences of performance and effectiveness of filtration on the dynamic and frequency range of vibroacoustic oscillations on the laboratory unit (Fig. 1).

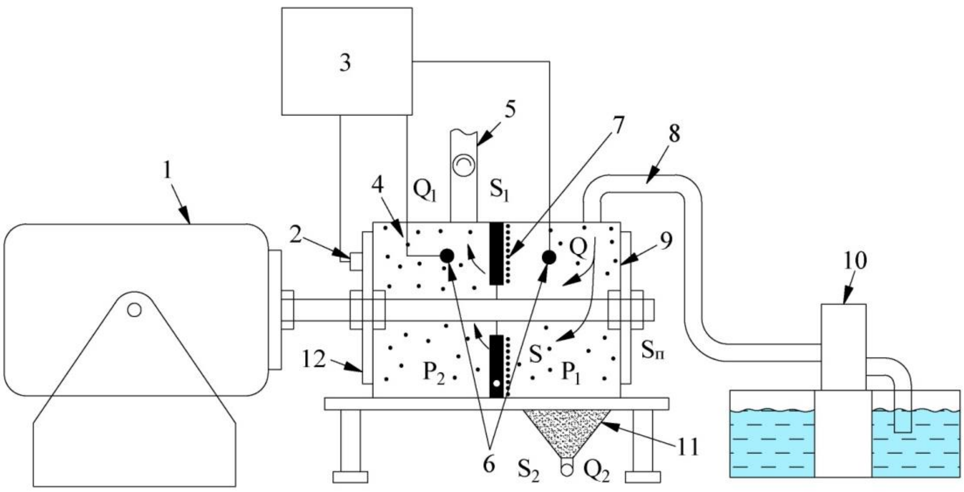

***Figure 1** Schematic diagram of a vibroacoustic filter*

1 – vibration exciter; 2 – acceleration meter; *3* – measurement unit; *4* – filtration chamber; *5* – outlet connection with pressure gauge; *6* – pressure sensor (strain gage transducer); *7* – filtering partition; *8* – inlet connection; *9,12* – pistons; *10* – pump; *11* – discharging gear.

The vibroacoustic filter is a chamber *4* separated with filtration partition *7* into two sections - initial suspension section and purified fluid section. Each section has pistons. Pistons *9* and *12* are driven with a vibration exciter *1* and make in-phase vibrations thanks to rigid connection between themselves through a metal rod. The suspension is fed to the filtering unit with a pump *10*. Pressure and performance in the initial suspension section are adjusted with the help of a valve installed in the input connection *8*. The pressure drop in the filter and the pressure in the sections are monitored with membrane strain gage transducers *6*, while the vibration parameters of the pistons are measured by acceleration strain gage transducer *2*. Signals from the transducers are furnished to measurement unit *3*. In the lower initial suspension section there is a conical discharging gear *11* for condensed product. The flow meter in the outlet connection *5* determines the filter performance.

During the study, we used various filter materials differing in method of their manufacture and structure: double twill-woven metal gauze, bronze and nickel metal-ceramic filters, filtering belting, and nitron. The filter element is designed in a «sandwich» from consisting of two perforated plates with filtering material located between them. As perforated plates, slotted screen (*Humboldt*) was used with the mesh size of 50÷70 µm. Fig. 2 shows hydraulic characteristics of these filters.

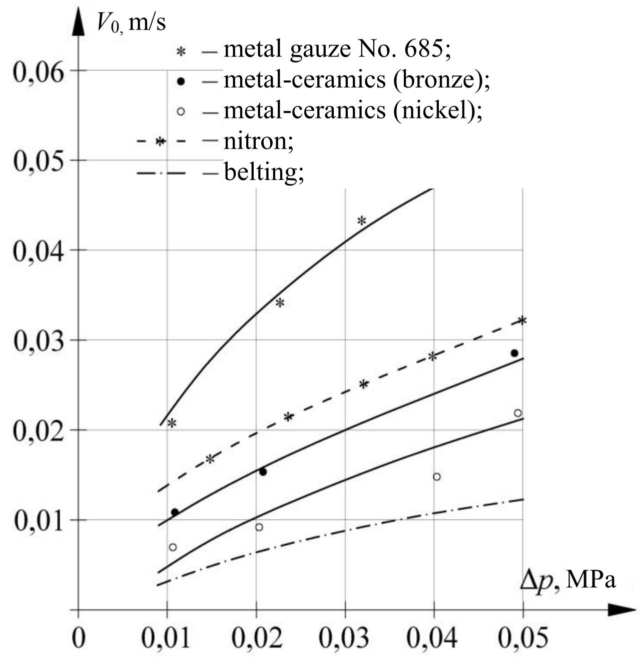

***Figure 2**. Hydraulic characteristics of filter materials*

During the experiment, suspension with its particles concentration from 100 to 2000 mg/l of a specified granulometric composition, typical for well waters, was fed to the filter element with simultaneous application of vibroacoustic oscillations of 5 to 120 Hz and oscillation velocity amplitude of 0.01 to 0.1 m/s. The pressure drop on the filters changed from 0.02 to 0.05 MPa. Different filter materials were used. The obtained results are presented in Figure 3. The diagrams show that regeneration of any filtering materials happens with certain vibration velocity amplitudes subject to conditions for counter-current flows occurrence.

It should be noted that there are three modes of impact of vibroacoustic oscillations. In the first mode, there are no counter-current flows ($V_m < V_0$) and there is no regeneration of the filter. In the second mode (transition zone), the amplitude of the oscillating velocity increases to cause sharp increase of filtration productivity ($V_m \approx V_0$). For the third mode, the filtration capacity ($V_m > V_0$) is maximum and continuous. Subsequently, the performance does not depend on the dynamics of impact and is practically equal to the productivity of purified water.

The transient mode is determined by the following [7]. For this range of dynamic impact, a gradual increase in the counter-current flow velocities is characteristic. Turbulent flows of fluid appear along the filtering material surface. All that contributes to more efficient filter regeneration. At a certain amplitude of oscillation velocity, a full restoration of the filtering material takes place, and further increase of oscillation velocity does not bring any increase in productivity. A dynamic mode of full regeneration of the filter depends on the type of filtering material used. Also, a mode of stable regeneration begins for dense filters with greater intensity of oscillations. Fig. 4 presented a graph of dependence of the required oscillating velocity amplitude on the filtering material and filtration process conditions (pressure difference).

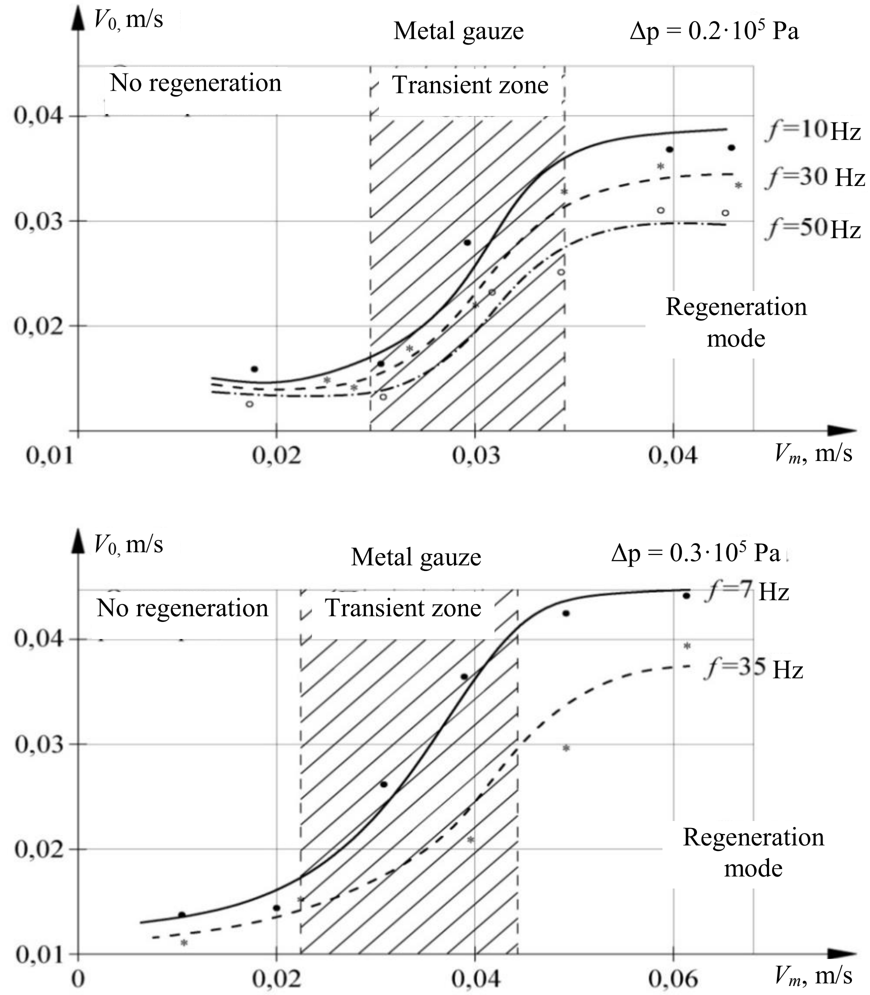

Figure 3. *Dependence of the filter specific productivity on the oscillating velocity V_m amplitude for metal ceramics (bronze) and metal gauze.*

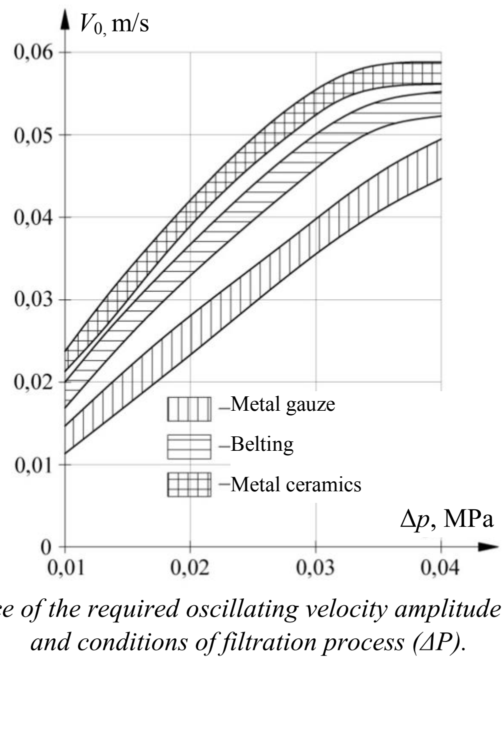

Figure 4. *Graph of dependence of the required oscillating velocity amplitude on the type of filtering material and conditions of filtration process (ΔP).*

The efficiency of waste water purification during the vibroacoustic filtering process was determined by the suspensions weight distribution depending on their granulation sizes. The following algorithm was employed to establish the filtration fineness. First, the dispersion composition of the initial suspension was determined, then the one of the treated suspension. The particle sorting coefficient for each interval was determined which value indicated the degree of filtration fineness of the filter under test.

The degree of filtration was established by the difference in the weight content of impurities in the initial fluid and in filtrate. Measuring of the weight content of suspended particles in the fluid was conducted either by filtration of 0.5 liter of fluid through a biological membrane filter or by using nephelometer LMF-69. The obtained results are presented in Fig. 5 and in Table 1.

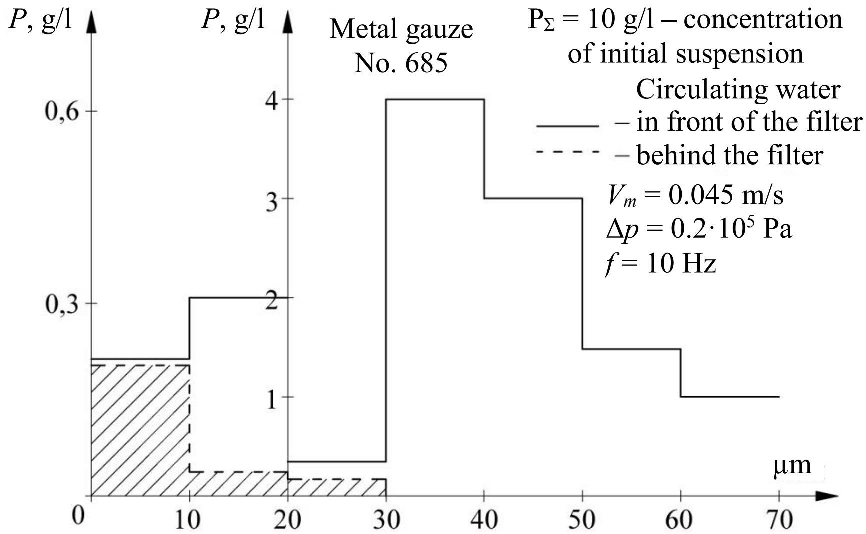

Figure 5. *Efficiency of vibroacoustic waste water purification with a metal filter*

The analysis of the obtained results makes it possible to conclude that filter materials with applied vibroacoustic oscillations can treat effluents to the required condition. In the purified water the suspensions concentration is always less than 150÷200 mg/l.

Table 1 *Dependence of the efficiency of purification on the type of the filtering material*

Type of filter material	Amplitude of oscillatory velocity, m/s	Suspensions weight distribution in filtrate as per grain size, g/l		
		0-10 μm	10-20 μm	20-30 μm
Metal gauze	0.045	0.14	0.09	0.07
	0.06	0.1	0.07	0.05
Belting	0.05	0.08	0.06	0
Metal ceramics (bronze)	0.05	0.07	0.03	0

When using metal gauze, the minimum size of captured particles is 25÷30 μm, and with metal ceramics filter (bronze) and belting – 20÷25 μm. Notably, metal ceramics and belting can treat water to a concentration of 100÷150 mg/l. Higher oscillating velocity amplitude results in higher purification effect. Clearly, it is associated with the fact that with great dynamic loads the number of particles accumulated in the area near the gauze increases.

Theoretical and experimental studies conducted have allowed developing and creating of a test prototype of a vibroacoustic filter for waste waters purification (Fig. 6).

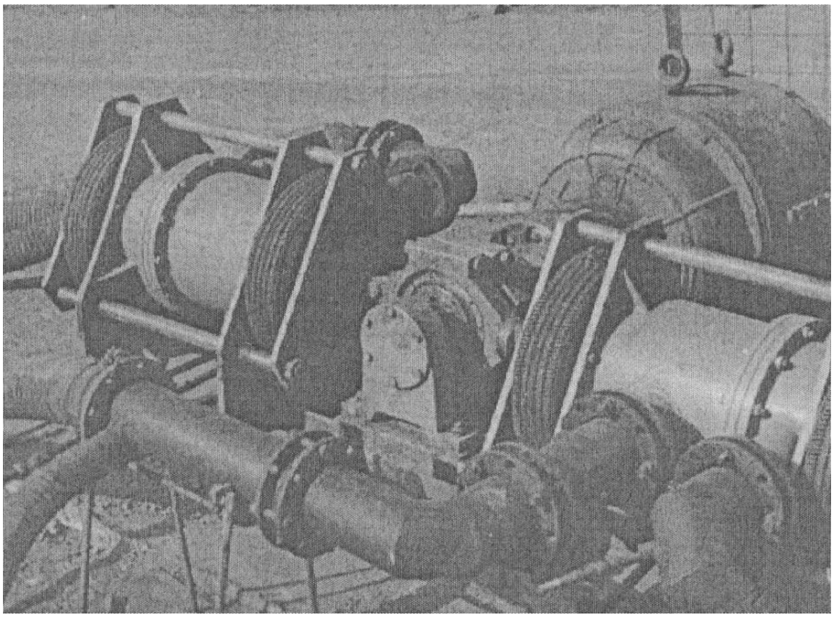

***Figure 6**. External appearance of the vibroacoustic filter (a pilot prototype)*

The filter contains two bodies arranged symmetrically relatively to the source of oscillations. A mechanical vibration drive is employed. Each body is divided with filtering partition into two sections. Pistons are installed into the end walls of the bodies using flexible elements with rigid interconnection. All four pistons are driven to oscillate from one vibration drive.

The task of the test research was to (i) determine the performance of the developed construction in the conditions close to production site and (ii) mastering the technology of effluents purification with our vibroacoustic apparatus in various stages of complex treatment schemes. Parameters of vibroacoustic filtration were studied relative to their granulometric composition, concentration of suspensions and physical and mechanical properties as well as modes of elastic oscillations.

During the experiment, we registered the flow rate of well waters under treatment; measured concentrations of suspended particles in initial well waters, in filtrate and in condensed product. The dispersion analyses of well waters and obtained product were conducted. Operation values of the vibroacoustic apparatus and current treatment facilities were also compared. Slime water was periodically taken from a conical sludge container. While conducting the tests, the vibroacoustic filter was built into a traditional circuit of purification. Experimental amplitude of the pistons oscillation velocity was changed (oscillation frequency from 5 Hz to 50 Hz) and the pressure drop on the filter element was varied in the range from 0.01 MPa to 0.1 MPa. Flat filter elements and cylindrical filter elements (cartridge-type) were employed. The pilot prototype was tested in wells of different regions of the Russian Federation. Qualitative and quantitative indicators of treated well waters are given in Table 2.

Table 2 *Results of industrial tests of the vibroacoustic filter*.

Type of filtering material	Parameters of vibroacoustic filtration process					Concentration of suspended matter in sludge container filtrate, mg/l
	Filter specific productivity m/hour	Concentration of suspended matter, mg/l in			Coefficient of filtration completeness, %	
		Initial suspension	Filtrate	Sludge		
Metal gauze	70	35	11	5000	69	20
Belting	25	35	5	4500	85,7	20
Metal gauze	70	100.8	33,6	23500	67	51
Metal ceramics (nickel)	32	100.8	28,4	19900	72	51
Metal ceramics (bronze)	38	100.8	30.4	24700	70	51
Metal gauze	70	200	100	400	50	170
Lavsan	70	202	79	8500	60.5	170

Results of industrial studies show potential perspectives of using vibroacoustical filters in water-sludge systems of mining enterprises.

The filter high specific productivity (up to 70 m/hour) ensures a high level of purification (70÷80% clarification). The developed construction shows its high performance and reliability; it does not require expensive servicing. Technological possibilities of vibroacoustic filters are practically unlimited and seem to have no analogs in the world.

Conclusions

Our investigations demonstrate that vibroacoustic filtration makes it possible to drastically increase the speed of waste waters purification of highly dispersed admixtures and increase the process efficiency. Introduction of the process will eventually reduce capital and operational expenses.

The developed vibroacoustic module is simple in manufacture, reliable in operation, is small-size and mobile.

The innovative element of this development is a possibility to use ultrathin cell filter elements manufactured with the use of nanotechnologies. This will help to essentially increase the quality of treated effluents and successfully solve environmental issues.

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