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Improvement of operating properties of drilling fluid by the method of cavitation treatment

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Abstract

It is experimentally shown that cavitation drilling mud conditioning allows improving such his operational properties.

The cavitation-pulsation device for drilling mud conditioning is a radically new type of technological. An advantage of this device is the possibility of generating high-pressure pulses in its flow passage which are used for operate on drilling fluid, their magnitude being several times as high as the total fluid pressure at the inlet of the device and their frequency being as high as 2,000 Hz and more. A second important advantage is the freedom from moving elements in its working area.

It is experimentally shown that at the change of properties of drilling fluid on viscidity from 5 with to 36 sec. and density from 0.8 to 1.8 g/cm3, dependence of frequency and amplitude of pressure oscillation on the output of device from his office hours practically does not depend on properties of solution.

Introduction

These works are conducted within the framework of implementation of project #1133 the Science and Technology Center in Ukraine (STCU). Collaborator on this project there was senior scientist at Brookhaven National Laboratory USA Dr. U.S.Rohatgi.

In studying the cavitation phenomena in local hydraulic resistances liquid flow regimes have been revealed under which in the channel of the local hydraulic resistance of the Venturi - nozzle type large cavitation formations periodical nucleation and their growth to certain sizes take place. On reaching the maximum sizes in accordance with the given flow regime the cavitation formation break-off occurs that is followed by its further carry-over and collapse as a whole in a pressure zone that involves a pressure pulse in the flow [1,2]. The principal characteristics of the oscillatory flow regime in the cavitation generator – outlet pipeline system to be determined are the frequency and amplitude of pressure oscillations in the system. The values of these parameters make it possible to assess the operational efficiency of the cavitation generator.

Indeed, the frequency of the cavitation oscillations under consideration is much higher that the first natural frequency of fluid oscillations in the hydraulic system downstream of the cavitating Venturi tube.

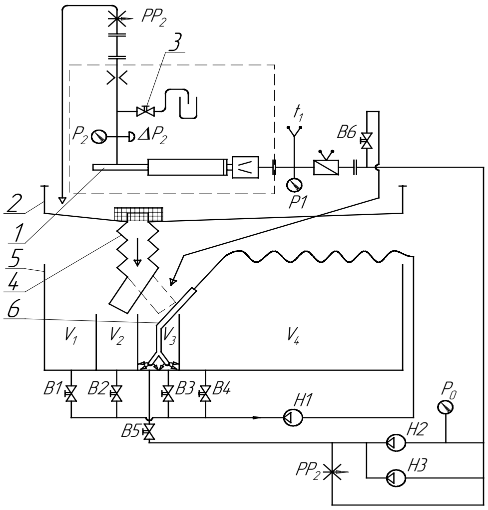
When sizeable cavities collapse in the fluid flow, extremely high pressures are generated. The pressure wave runs downstream from the collapse center to considerable distances with little or no damping (as long as 2.0 m in the experiments) while the pressure wave running upstream is damped by a new cavity that has grown by then as evidenced by the absence of oscillations at the Venturi nozzle inlet, but it takes part in the initiation of reverse flows and sets the stage for the detachment of the new cavity. In such a manner, a self-synchronizing process of cavity detachment and collapse is set up [3].

Intensifying dispersion processes by using hydrodynamic cavitation and supercavitation in place of ultrasonic cavitation has, as investigations have shown, the following advantages: the energy consumption and metal intensity of supercavitation devices is much lower; they are simple in design, and they show only slight cavitation wear of the flow passage and feature continuous operation, high efficiency and a wide range of cavitation cumulative effect.

In paper on the example of waters solutions possibility of work of device is shown in the wide range of parameters of suspensions that grounds for the use of pulsating stream, which is created on the output of device for work on the different types of drilling fluids and cements solutions which are widely used in oil-and-gas industry [4].

Main Heading

Experimental studies of the cavitation-pulsation plant for suspension dispersion were conducted on the updated hydraulic bench using the hydraulic circuit shown in Fig.1.



1. Hydrovibrator, H_2, H_3 – UN200/320 pumps H=320 atm, Q=3.3 l/s, 2.Collecting tank V_{np}=12 m^3
H_1 – pump H=1.8 atm, Q=8 m^3/h, 3.Sampler,
B1 ... B4 – valves D_y=40 mm, P_y=10, 4.Reverser,
PP_1, PP_2 – electrically operated throttles,
5. 4-section tank V_Σ =36 m^3, V_2= V_3=3 m^3
B5 - valve D_y=150 mm, P_y=6, 6.Vortex agitator,
B6 - valve D_y=20 mm, P_y=400

Fig.1 Pneumohydraulic circuit of plant for suspension dispersion.

The chart of stand has the open system of turn of liquid which after passing through the Cavitations device (Disperser) is going in the collecting tank.
On the Fig. 2 the picture of general view of hydrovibrator device is resulted with a connecting thread for log of hole.

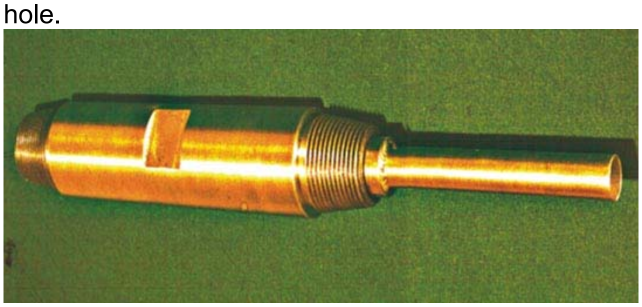


Fig.2 Photo of cavitation hydrovibrator.

Recall that the P_2/P_1 ratio is approximately equal to the cavitation parameter τ calculated from the fluid velocity at the throat section of the converging-diverging portion of the flow passage of the disperser in a given operating regime.
As an example, Fig. 3 depicts a time oscillogram of the pressure P_2 and the disperser body vibration acceleration a_2 at the outlet of disperser at an inlet pressure $\overline{P}_1$ =21 bars and a cavitation parameter τ =0.152.

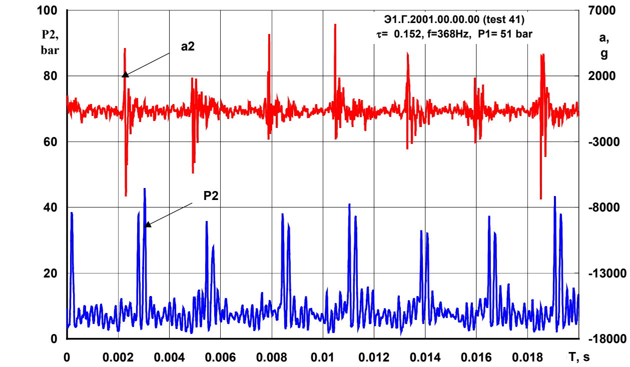


Fig.3 Oscillogram of the pressure P_2 and vibration acceleration a_2 measured during plant operation.

Figs. 4–5 show the peak-to-valley amplitude dP_2 and frequency f of fluid pressure oscillations at the disperser outlet versus cavitation parameter τ when operating on water under bench conditions at different values of the pressure P_1 at the device inlet.

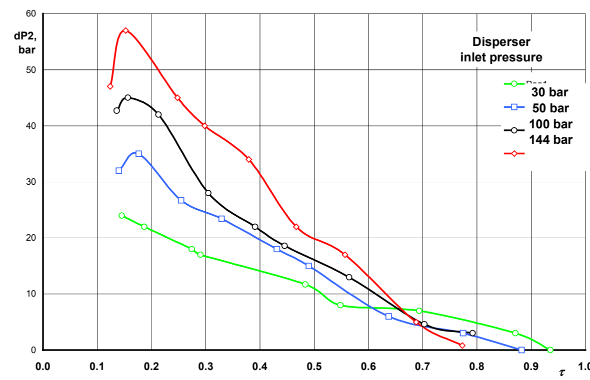


Fig.4 Peak-to-valley amplitude dP_2 of fluid pressure oscillations at the disperser outlet versus cavitation parameter τ at different pressures at the plant inlet.

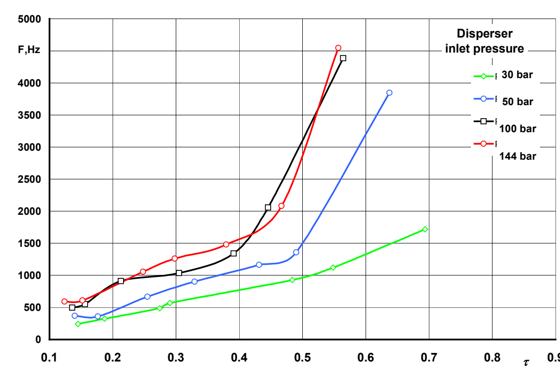


Fig.5 Frequency of fluid pressure oscillations at the disperser outlet versus cavitation parameter τ at different pressures at the plant inlet.

As illustrated, with increasing cavitation parameter τ the peak-to-valley amplitude dP_2 of fluid pressure oscillations at the disperser outlet increases, reaches its maximum at τ =0.18-0.2 and then gradually decreases to zero where the cavitation generator ceases to operate. The frequency of fluid pressure oscillations at the device outlet increases nearly linearly from 243 Hz to 1720 Hz at the minimum device inlet pressure and from 591 Hz to 4545 Hz at the maximum device inlet pressure.

As seen from the graphs, steady operating regimes of the disperser take place in the cavitation parameter range 0.15 to 0.56 at high device inlet pressures and 0.15 to 0.69 at low device inlet pressures.

To study the effect of the properties of different suspensions, the plant was tested on a water-clay suspension doped with sodium acrylate, a surface-active additive (0.3% of solid-particle weight), and a water–clay suspension doped with Dispex-40, a depressant (0.5%). Measuring of pulsations of pressure in these tests was conducted in an outward pipe on the output of aggregate.

Figs. 6–7 show the frequency f and peak-to-valley amplitude dP_2 of fluid pressure oscillations at the disperser outlet versus cavitation parameter τ for the basic disperser embodiment at an inlet pressure P_1=100 bar when operating on a 40% water–clay suspension and water. Hatched bars mark the operating regimes in which samples were taken for dispersion degree analysis.

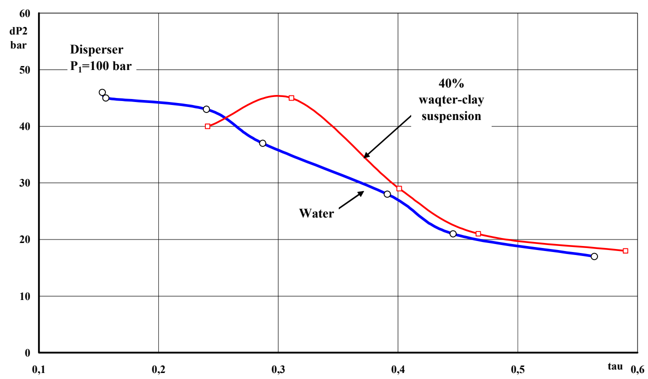


Fig.6 Experimental dependences of the peak-to-valley amplitude dP_2 of fluid pressure oscillations at the disperser outlet on cavitation parameter τ when operating on a 40% water-clay suspension and water.

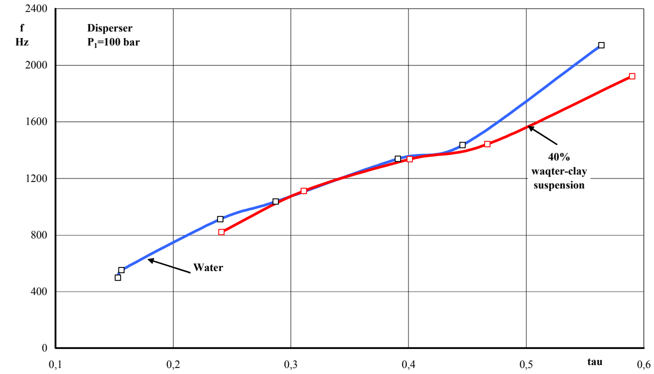


Fig. 7 Experimental dependences of the frequency of fluid pressure oscillations at the disperser outlet on cavitation parameter τ when operating on a 40% water-clay suspension and water.

The cavitation parameter range of steady operation of the cavitation generator of the plant disperser is 0.15–0.6 both for water and water–clay suspension, the frequency and peak-to-valley amplitude of the generator-produced fluid pressure oscillations at the disperser output depending almost not at all on the type of working fluid. With increasing cavitation parameter, the fluid pressure oscillation frequency increases linearly from 91 to 2142 Hz while the fluid pressure oscillation peak-to-valley amplitude at the disperser outlet increases, reaches its maximum at τ= 0.15–0.22 and then smoothly decreases.

To assess the operational efficiency of the plant, the dispersion degree of a water–clay suspension with solid-particle weight content from 10% to 40% in different cavitation parameter regimes of disperser operation was determined. The obtained dispersion degree was such that the size of 95% of the particles was less than 10 μm and the size of 80% of the particles was less than 5 μm even after one passing through the disperser.

How example Fig. 8 shows, on a logarithmic scale, the percentages of solid particles of different size determined by the analysis of samples taken at the outlet of the plant in different regimes of its operation on a 40% water–chalk suspension. Only one dispersion degree of the suspension at the inlet of the plant is plotted because the others are identical.

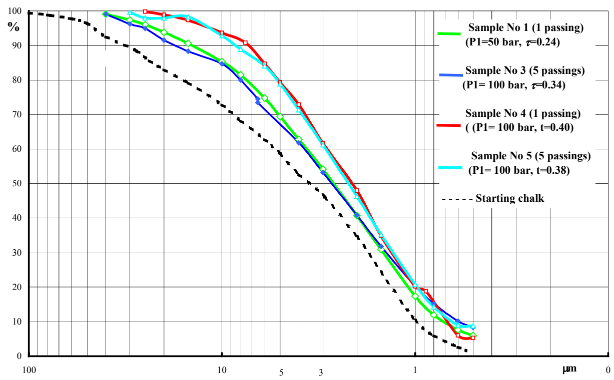


Fig.8 Chalk dispersion degree for different operating regimes of the plant

Thus the chalk dispersion degree improves as the operating frequency of the disperser increases. When the operating regime of the plant is such that τ =0.38 – 0.40, the dispersion degree does not depend from pressure on the input of aggregate.
Before conducted researches of capacity of cavitation hydrovibration a on solutions on oil basis confirmed his descriptions got on water and water-clay solutions.
Present preliminary experimental information on the exploration work of Russia with the use of cavitation hydrodynamic device, at washing of mining holes by clay arilling mud, showed efficiency of their use for the improvement of operating properties of drilling fluids and intensification of technological processes with beginning to swing of liquid environments in a mining hole, such as boring drilling and simulation of the prepared mining holes of the different setting.

Conclusions

The cavitation parameter range of steady operation of the cavitation generator of the plant disperser is 0.15–0.6 both for water and waters suspensions, the frequency and peak-to-valley amplitude of the generator-produced fluid pressure oscillations at the disperser outlet depending almost not at all on the type of working fluid.
With increasing cavitation parameter, the fluid pressure oscillation frequency increases linearly from 91 to 2142 Hz while the fluid pressure oscillation peak-to-valley amplitude at the disperser outlet increases, reaches its maximum at τ = 0.15–0.22 and then smoothly decreases.
It has been shown experimentally that for the suspension viscosity and density varying from 5 to 36 s. and from 0.8 to 1.8 g/cm^3, respectively, the disperser pressure oscillation frequency vs. cavitation parameter relationship in steady operating regimes of the cavitation generator does not depend on the properties of the medium, the frequency increasing linearly with cavitation parameter.
The pressure oscillation amplitudes depend almost not at all of the type of fluid too. This makes it possible to try out the units and assemblies of the plant on water, which is more economic and easier.
Cavitation drilling mud conditioning allows by comparison to existent industrial technologies of application of drilling fluid: - in 1,5 - 2 times to increasing dispersion; on 10 - 20% to lower screen density; on 10 -15% to reduce the water loss; to better the absorbing properties; to decrease power intensity of process of destruction of rock; to decrease the twisting moment enclosed to the log of hole; to rev up mechanical boring drilling on 8 - 34%; to promote firmness rock cutting tool on 24 - 29%.

Acknowledgments

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