AGH DRILLING, OIL, GAS • Vol. 33 • No. 4 • 2016

http://dx.doi.org/10.7494/drill.2016.33.4.693

Alexandr N. Davydenko*, Alexandr F. Kamyshatsky**

TECHNOLOGY FOR PREPARING WASHING LIQUID

The evolution of well drilling techniques is inextricably linked with the improvement of drilling/washing fluids that are complex heterogeneous poly-disperse systems. The variety and, sometimes, contradictory character of requirements for washing fluid, as well as rapidly changing geological and technical conditions of well drilling cause the need for applying "customized" drilling fluids having certain properties that determine their functionality. The technological properties of drilling fluids are substantially determined by their stability, i.e. constant main parameters of disperse system: fineness (specific surface) and uniform distribution of the dispersed phase in the dispersion medium.

The kinetic stability refers to the ability of dispersed particles to keep suspended under the influence of Brownian motion, i.e., stability with respect to mass gravitational forces. In addition to the Brownian motion, the kinetic stability factors are variance (the most important factor, the higher the variance, the more stability), viscosity, density difference between the dispersion medium and the dispersed phase.

Thus, the most promising direction related to washing fluids is to obtain high-quality stable systems.

While preparing the washing fluids using existing methods, it is impossible to reach the full dispersion of dispersed phase. Therefore, further dispersion of the dispersed phase of washing fluids using different dispersants is an important problem to be studied. Dispersing enables reducing the amount of solid phase in the washing liquid preserving specified structural and mechanical properties. The lower is the quality of the clay, the greater is the dispersion effect.

The analysis has showed that super-cavitation is the most promising technique for treatment of washing fluids. Super-cavitation occurs when axisymmetric bodies are flowed around by liquid. The operating principle of SC-mechanisms is that flow slipping around the cavitator results in the formation of super-cavities that close directly in the flow, far away

* National Mining University, Dnipropetrovsk, Ukraine – Doct. Sci. (Tech.), Prof.
** National Mining University, Dnipropetrovsk, Ukraine – Cand. Sci. (Tech.), Assoc. Prof.

from the working surface of the machine. The unsteady tail section of the cavity generates fields of cavitation micro-bubbles that, when collapsing, intensify the dispersion process, with the apparatus working surfaces not being affected by cavitation erosion and the service life not depending on the modes of cavitation treatment. The decisive factors are the number and size of cavitation bubbles.

For calculating basic parameters of cavitation disperser, the Bernoulli equation and the continuity equation for sections 0–0 and 1–1 (see Fig. 1) have been solved.

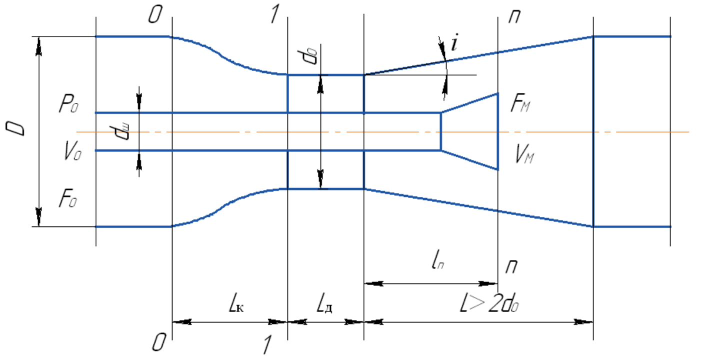

Fig. 1. Diagram of cavitation disperser

$$H = P_0 + \frac{\rho \cdot V_0^2}{2} = P_1 + \frac{\rho \cdot V_1^2}{2} + \Delta h_{0-1} \tag{1}$$

where H is pump pressure, p is density of washing fluid, and Δh_{0-1} is losses in confusor:

$$Q_0 = Q_1 = Q_i \,,\; V_0 F_0 = V_1 F_1 = V_i F_i \tag{2}$$

where F_0, F_1, F are respective cross sections;

$$\Delta h_{0-1} = \frac{\xi_c \cdot \rho \cdot V_1^2}{2} \tag{3}$$

where ξ_c is coefficient of hydraulic losses in confusor.

When transiting from the wide section of confusor to the narrow one, pressure decreases. In order to reduce the pressure drop, the confusor shall have a sinusoidal shape and a length equal to the pipe diameter at cross section 0–0 (see Fig. 1).

The angle of diffusor slope is defined assuming that there is no cavitation on the walls of the generator; in accordance with recommendations, the diffusor slope angle is $y < 25°$, the diffusor section length is $L > 2d$.

The hydraulic losses on the cavitator are calculated according to the formula:

$$\Delta h_c = \xi_{cav} \frac{\rho \cdot V_{cav}^2}{2} \tag{4}$$

where V_{cav} is velocity at the place of cone flow fluid in the diffusor.

The total losses on the cavitation disperser are:

$$\Delta h_{KD} = \left(\xi_c + \xi_d + \xi_z\right)\frac{\rho \cdot V_z^2}{2} + \left(\xi_{cav}\right)\frac{\rho \cdot V_{cav}^2}{2} \tag{5}$$

where ξ_{cav} is the coefficient of hydraulic losses on the cavitator.

The intensity of the cavitation treatment should depend on geometric characteristics of supercavity, number and size of cavitation micro-bubbles behind super-cavity. Since super-cavity size (intensity of cavitation treatment) is controlled by axial shift of cone in the diffusor, in order to describe the intensity of hydrodynamic cavitation, flow chocking coefficient k_c is introduced: where F, F are cross sections of the cone and the diffusor, respectively; D_c, D_d are base diameters of the cone and the diffusor, respectively.

Taking into consideration the continuity equation and the flow chocking coefficient, the cone flow rate is equal:

$$k_c = \frac{F_c}{F_d} = \frac{D_c^2}{D_d^2} \tag{6}$$

where d_c is the cone's diameter; Q is consumption rate of washing fluid.

The flow chocking coefficient varies within the range k_c = 0.6–0.8, insofar as therein the intensity of rate fluctuation is maximum, which enables controlling the intensity of cavitation effect within a wide range.

$$V_c = \frac{Q}{0{,}785 \cdot d_c^2 \cdot (1/k_c - 1)} \text{ m/s} \tag{7}$$

The nature of cavitation oscillations occurring during the cone flow is similar to that of phenomena known in hydrodynamics as *Strouhal frequencies*. For these oscillations, a linear dependence of frequency on rate of approach flow and an inverse dependence on specific dimension (hydraulic diameter) are typical:

$$f = \frac{Sr \cdot V}{d_g} \tag{8}$$

where *Sr* is the Strouhal number (dimensionless quantity, one of non-steady flow similarity criteria).

The Strouhal number is a function of the Reynolds number; within the range 200 < *Re* < 200,000 the empirical law of Strouhal number constancy: *Sr* = 0.2–0.3. The final formula for calculating the frequency of cavitation oscillations is:

$$f = \frac{Sr \cdot Q}{0{,}785 \cdot d_c^3 (1/k_c - 1)(1/\sqrt{k_c} - 1)} \text{ Hz} \tag{9}$$

In view of the research was developed the experimental model cavitation disperser, patent novelty is confirmed Ukraine (Fig. 2).

Drilling fluid on the discharge line enters cavitation disperser. When flow around the cone section is formed in which liquid drip completely absent – there supercavities. To be able to regulate operational parameters of cavitation flow dispersant cone configured to axial movement. The size supercavity depends on the flow rate and as a result of radial flow gap between the cone and diffuser.

In the new design the stem of the cone-wrapping is not fixed rigidly, but put on a special spring 4, with a certain stiffness, which ensures free movement of the coneflow in the diffuser of a cavitation disperser. The edge of the cone of flow is provided with toothed notches 5 which increase its contact area with the flowing disperse system and also provide for additional grinding of the large dispersed phase by dissection.

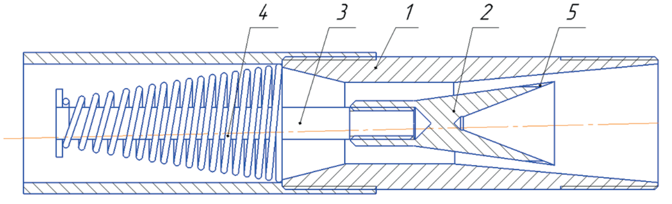

Fig. 2. Cavitation disperser

The actual operational parameters of cavitation disperser (magnitude and frequency of cavitation pressure oscillations) have been measured by recording the process in different operation modes (varying pumping rate and flow chocking coefficient inn cavitation disperser). The installation included a cavitation disperser, a pump, a depositing tank, a suction pipeline, a pressure pipeline, and gauges.

Figure 3 shows the results of tests of frequency dependence of cavitation disperser at a pumping rate of $Q = 0.003$ m^3/s. The difference between the experimental and the theoretical data ranges between 15–20%.

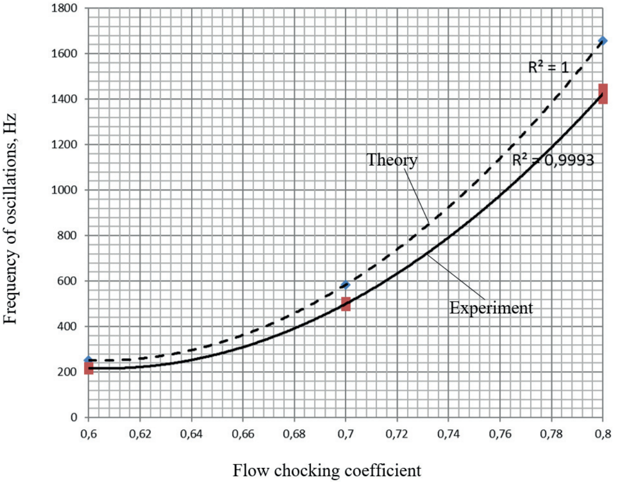

Fig. 3. Dependence of frequency of cavitation oscillations on flow chocking coefficient at $Q = 0.003$ m^3/s

CONCLUSIONS

As a result of theoretical and experimental research, a technology for preparing stable finely dispersed washing fluids has been developed using the hydrodynamic effect of super-cavitation.

The hydrodynamic super-cavitation that occurs when the fluid flows around axisymmetric bodies has been justified to be the most promising technology in terms of energy efficiency for the preparation of washing fluids.

A new design of cavitation disperser has been developed; its novelty has been certified by patent of Ukraine.

The flow chocking coefficient k_c is the key controllable parameter influencing the intensity of cavitation treatment.

The cavitation disperser enables the effective dispersion of washing liquid components and can be commercialized in the drilling practice.

REFERENCES

[1] Davidenko A.N., Kamyshatsky A.F.: *Upravlenie svoystvami promyivochnyih zhidkostey s pomoschyu kavitatsionnogo dispergatora*. Gornyiy zhurnal Kazahstana, no. 4, 2013.

[2] Davydenko A.N., Kamyshatsky A.F., Sudakov A.K.: *Innovative technology for preparing washing liquid in the course of drilling*. Science and Innovation no. (11)5, 2015, pp. 5–13.

[3] Davidenko A.N., Kamyshatsky A.F.: *Patent 68524 A Ukraine, MKI 7 E 21 V 21/06. Pristriy dlya pryhotuvannya burovykh ridyn*, no. 2003065862. Zayavleno 24.06.2003, Publ. 16.08.2004, Byul. no. 8, p. 3.