ACOUSTIC FIELDS GENERATION BY PLASMOIDS IN THE WELLBORES

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In this paper it is proposed a method of acoustic pulses generation in a wellbore by means a plasma gun which located at the well mouth. Acoustic measurements results are presented. It is shown that the wellhead pressure affects on the amplitude and hydrodynamic pulse shape, on its attenuation and the impact intensity at the wellbottom zone. It was determined the range of wellhead pressures at which a impulse force of wave reaches the highest values at the well bottom zone. It is shown that this method can favorably affect on the oil well productivity.

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INTRODUCTION

At this time low-temperature plasma is not only used as a science research object but as a working medium under different industrial tasks solution. Thermal plasma high power density and temperature determines the high speed of thermal impact on the body and provides high chemical reaction speed between plasma constituents. It permits to develop a new effective technologies and equipments which have good materials consumption efficiency, power efficiency and environmental safety. The plasma engineering and technology is one of the industry fields where production interests and applied researches are firmly weaved with fundamental science. The range of thermal plasma applications is very wide: plasma formations can serve as sources of charged particles [1], as a working medium in space electrojet engines [2] and realizes the hypervelocity acceleration of bodies [3, 4], modeling the space vehicles entry conditions into the atmosphere, as well as, their using as a source for-plasma in a thermonuclear fusion research [5]. The plasma technology application can significantly improve the productivity of melting and thermal aggregates [6], new coating types [7].

In addition, plasma discharge in water are used as a intensive sources of acoustic fields [8]. This discharge type is not only the object of scientific interest [9], but also it has wide application [10].

In the past decades it was developed a wave impact techniques of electric discharge on the producing layers for problem solution concerning production of liquid hydrocarbons [11, 12]. However, these methods have a number of limitations and complicated technical solution which includes several kilometers immersion of the plasma generator which is structurally combined with energy storage and realizing the discharge in nonconductive liquid.

It should be noted that such high voltage submersible equipment operates under adverse environmental conditions: pore pressure can reach several hundred atmospheres and the temperature – 373 K. The extremely restricted conditions of a deep devices arrangement in harsh environments dictate specific solutions faced to electrical engineers. A specific feature of these devices with the coaxial power electrical circuit of the discharge is the fact that their high-voltage pulse capacitors, high-current switch and the discharge electrode system is placed in a steel tubular body of small diameter (about 140 mm) which is lowered on the high-voltage cable into a steel case pipe to the well perforation zone.

It should be noted that the dynamics of the plasma formation and, consequently, the characteristics generated by means of acoustic waves depend on the fluid pressure in the well. In addition, the effectiveness of the impact depends on the state of the reservoir. These circumstances restrict the use of such devices. So on the Ukraine deposits it is possible to process vertical wells up to 3.5 km by means of using this method.

To remove these shortcomings it is reasonably to use the controllable powerful energy sources which would permit to receive the required acoustic field regardless of well fluid electroconductivity conditions, the confining pressure, the pore pressure and the reservoir depth, and to reduce repair time and effort.

In this regard, pulsed plasma generators [5, 13, 14] (plasma guns) are of great interest. It operates by means of high pressure pulsed arc discharge and placed on the wellhead. Basic advantage of these generators as compared to explosive sources is that not only large concentrated plasma streams energy can be released (10 MJ and more) but also to control the energy release rate. It will provide required fluid acoustic pulse characteristics and permits to avoid dependence on the electrically conductive fluid properties. The location of the elastic wave source at the wellhead removes its size restrictions and allows to control the conditions under which plasma formation expansion takes place.

The generation of acoustic fields in the liquid by means of the injection into her dense plasmoid, which is formed by powerful plasma source, was described for the first time in [15]. However in this work the excitation of acoustic pulses was realized in the open space. But for solution of this problem it should place generators in fluid-filled wells. The computer simulations results [16] show that it is possible the situation when steam-gas cylinder expands one-dimensionally deep into the well and acts on fluid as a piston. Besides of that, excited oscillation modes in the well and its damping will considerably differ from the amplitude attenuation in the "free water." On these circumstances it was rightly pointed out in [17].

In this connection it is necessary to substantiate conditions under which it will be possible one-dimensional expansion of plasmoids. Additionally it should be determined the energy and time parameters of the arc discharge, at which in the well–acoustic waveguide, solitary elastic hydrodynamical pulses are generated with such characteristics under which it is possible to increase well productivity.

1. CONDITIONS OF SOLITARY ELASTIC PULSES GENERATING

1.1. CONDITIONS OF SOLITARY ELASTIC PULSES GENERATING BY MEANS OF PLASMA FORMATION

When the plasma generator is located in the well mouth, for effective impact on the bottomhole zone it is necessary to excite a solitary pulse in the fluid that fills the well - acoustic waveguide. The realization of this method of elastic waves excitation needs some conditions which are determined below.

The elastic waves excitation in a liquid can be realized by means of the shift of the boundary between liquid and the other medium - medium of wave source. Elastic waves excitation by means of a solid-state source is rather simple character from the theoretical view point. However, the high power wave's excitation by means of moving the piston leads to a number of technical difficulties. It should also be noted that the efficiency of energy conversion into acoustic power decreases at increasing the piston mass [8].

Electric-discharge source (spark) is more simple and reliable in engineering work. When the waveguide is filled conductive liquid it is also possible to initiate a discharge under electrical breakdown of liquid [9].

Regardless of the electrical liquid properties the discharge can be realized in the gas preliminary filled the upper part of the vertical waveguide. There are two possible cases. In one case the gas-filled region covers the waveguide section completely.

In this situation the characteristic time of disturbance propagation in the plasma-forming medium

$$t_1 : d_B / v_S , \qquad (1)$$

where the d_B – waveguide diameter, v_S – sound speed in the gas medium.

During this time, the difference in the displacement of the fluid boundaries at different points of its surface was of the:

$$\mathrm{D}x = \frac{\P p(t)}{\P t}\frac{1}{r_0 c} t_1^2 , \qquad (2)$$

where p – pressure of the gas cavity, c – sound speed in liquid, r_0 – liquid density.

We assume that during the discharge lifetime t_D the cavity pressure reaches maximum value $p_{\max}$. Then assuming $\P p(t) / \P t$ » $p_{\max} / t_D$ we get

$$\mathrm{D}x = \frac{p_{\max}}{t_D}\frac{1}{r_0 c}\left(\frac{d_B}{v_S}\right)^2 = \frac{p_{\max}}{r_0 c v_S}\frac{d_B}{v_S t_D} d_B . \qquad (3)$$

At elastic waves generation there are achievable relations $p_{\max} / (r_0 c v_S) = 1$ and $d_B / \left(v_S t_D\right) = 1$. Consequently $\mathrm{D}x = d_B$ and boundary surface of mediums can be considered as flat. Then under discharge realization in the gas-filled gap it can be excited elastic unipolar pulse with a flat wave front in waveguide [18].

In the second case, the gas piston formation occurs under plasma jet injection into the liquid from the region which is only partially overlapping waveguide section. We suppose that region filled by gas is cylinder of height h and diameter $d_n = d_B$ which is smaller than the waveguide diameter d_B. For simplicity, we assume that cylinder axis coincides with cavity axis. Note that the discharge in such a cavity is conveniently realized by means of electrodes placed on the cylinder ends.

After initiation of the discharge in the gas gap the energy is released by a certain law $E(t)$ and it is converted into the plasma formation internal energy W and is expended in doing work A :

$$E = W + A . \qquad (4)$$

If the phase boundary is not flat, then at the end of the energy input into the cavity the inertia kinetic energy of liquid is partially converted to stretching potential energy.

If phase boundary is flat, the process of converting the kinetic energy into stretching potential energy is impossible [18] and gas expansion will lead to the radiation of a solitary compression pulse.

From practice it is known [9] that the discharge realized on the rigid plane surface liquid discharge leads to the cavity formation which has the hemisphere shape. The motion law of such a cavity is the same as for a cavity in an infinite liquid, but in which it has been released twice as much energy. In this case, at the initial stage of expansion the rate of the sphere radius R changes [9]:

$$R\& = \sqrt{p / r_0} . \qquad (5)$$

Consequently, in a cylindrical waveguide the criterion of the solitary pulse excitation is the conditions under which medium boundary can be considered as flat and its movement is translational, that is, when the gas cavity diameter exceeds the waveguide diameter:

$$2R > d_B . \qquad (6)$$

We estimate the discharge parameters at which this condition is satisfied. Suppose that during the time t_D of electric current in gas it was released energy E. In accordance with (6) the gas volume at the end of the discharge:

$$V > p d_B^3 / 12 . \qquad (7)$$

The average liquid flow velocity through the waveguide cross section of the area $S = p d_B^2 / 4$ is:

$$\left\langle v \right\rangle = \frac{V}{t_D S} = \frac{4V}{t_D p d_B^2} > \frac{1}{12} p d_B^3 \frac{4}{t_D p d_B^2} = \frac{1}{3}\frac{d_B}{t_D} . \qquad (8)$$

In this case the kinetic energy of liquid $E_K : S r_0 c \left\langle v \right\rangle^2 t_D / 2$ or

$$E_K : \frac{p d_B^2}{4} r_0 c \frac{d_B^2}{2 Ч 9 t_D^2} t_p = \frac{p}{72} r_0 c \frac{d_B^4}{t_D} , \qquad (9)$$

the potential energy of cavity:

$$\mathrm{P} = p_0 V > p d_B^3 p_0 / 12 , \qquad (10)$$

and the gas internal energy according to [2]:

$$W = p_n V / (g - 1) > pp_0 d_B^3 (g - 1)^{-1} / 12\,, \quad (11)$$

where p_0 – static (equilibrium) pressure in the fluid, p_n – gas pressure, V – gas volume, g – gas adiabatic index.

Then, according to (4, 9, 10 and 11) we can estimate the energy which is necessary to release under discharge in liquid for plasma injection with the purpose to generate solitary elastic pulse

$$E > E_K + \text{P} + W = \frac{p}{12} d_B^3 \left(\frac{r_0 c d_B}{6t_D} + \frac{g}{g - 1} p_0 \right). \quad (12)$$

1.2. THE DETERMINATION OF DISCHARGE ENERGY AND TIME PARAMETERS

In this paper it is proposed the technique of bottomhole zone (BHZ) treatment, which should be considered as vibration-wave method in accordance to the classification of [19]. This method and the mechanical equipment of its realization were proposed by S.M. Gadiev in the 60's and it is called "vibration" in [20]. Under the embodiment of this method it uses a hydraulic thrust load of the liquid pumped into the well. Used in this method spool valve or flap types vibrators excite quasi-sinusoidal waves with frequency from 50 Hz to 1.5 kHz. The excited wave amplitude are nearly a few atmospheres. It should be noted that such method is implemented under depression [19] as a rule.

The main effect of the vibration-wave impact on the BHZ is achieved, according to the author [20], due to the cracks formation in the BHZ, the influence on the rheological liquids properties, increase the mobility of liquids in the stratum, etc.

At this moment in spite of hydrodynamic mechanical type generators attractiveness it is not widely used because of its unreliability, low efficiency and greater power inputs [19].

For further discharge characteristics evaluations we (accordingly to [19]) will suppose that for the effective impact on the BHZ it is necessary to excite the hydrodynamic pulse in the well, pulse fundamental frequency $f_{0,\max} » (2t_D)^{-1}$ is the order of kilohertz and the pulse amplitude A_Z should be 10 atm at the well bottom:

$$f_{0,\max} = 10^3 \text{ Hz}, \quad (13.1)$$

$$A_Z = 10^6 \text{ Pa}. \quad (13.2)$$

To determine the pulse amplitude A_0 at the wellhead it is necessary to consider the fact that under sound propagation the large tangential velocity component gradient appears in the liquid wall layer. This gradient causes viscous dissipation of energy [21]. In this case the attenuation coefficient is equal to the energy dissipated per unit time per unit wall surface per unit pipe length which divided by twice the total energy flux through the tube cross section:

$$a = \frac{\sqrt{w}}{\sqrt{2} R_T c} \left[\sqrt{n} + \left(\frac{c_p}{c_V} - 1 \right) \sqrt{c} \right], \quad (14)$$

where $w = 2pf$ – wave cyclic frequency, R_T – tube radius, n, c, c_V and c_P – kinematic viscosity, thermal diffusivity and heat capacity of the fluid at constant volume and pressure.

We note that a attenuation coefficient is inversely proportional to the tube radius. This indicates on the using of the waveguide as well casings which have a minimum diameter R_T = 146 mm.

Currently wells depth can reach z : 5 km.

The amplitude of the plane acoustic wave traveling along the z axis decreases with distance as e^{-az}, and intensity – as e^{-2az}. Then:

$$A_0 = A_z e^{az}. \quad (15)$$

Substituting numerical values in (13.2), (14) and (15) we can see that the pulse amplitude should be on the order of 4 MPa near the wellhead.

However, the realization of the required plasma formation regime of expansion is rather serious technical problem under taken up radius R_T, even when the fluid pressure at the wellhead p_0 is equal to atmospheric pressure. As thus the released discharge energy according to (12) must exceed the amount of 100 kJ and the generator electrode system should have a rather complicated construction.

In addition, the fluid in the well is a two-phase system – liquid encapsulating the gas bubbles. In such medium the sound attenuation increases by several orders of magnitude, if the bubble is resonating with the incident sound wave. The bubble resonance frequency can often be determined by the formula Minnaerta [22]:

$$w_0 = R_0^{-1} \sqrt{g_g p_0 / r_0}\,, \quad (16)$$

where p_0 is the equilibrium liquid pressure, R_0 – is the gas bubble radius, for which the adiabatic index equals g_g.

It is seen from the formula (16) that the resonance can be avoided by increasing the pressure of liquid.

The pointed above circumstances forces to realize the discharge in the tube with a radius $d_B / 2 = R_T$. For this purpose, it is more convenient to use a segment of standard pump-compressor pipe (PCP) with diameter d_B : 5 cm. Then, even under the liquid pressure in the 5 MPa the calculations by formula (12) gives the value of E ; 3 kJ, and at p_0 = 1 atm E ; 2 kJ.

However, for the estimation of input energy in discharge it must take into account wave energy loss under going from the pipe with cross section $S = pd_B^2 / 4$ to the pipe with cross-section $S_2 = pR_T^2 / 4$. In this case, the ratio of energy flux of transmitted and incident harmonic waves is $D = 1 - \left((S_2 - S) / (S_2 + S) \right)^2$ [21], which for the above values d_B and R_T yields D ; 0.4. Consequently, in the pipe with cross section S the energy flow and input energy must satisfy the following conditions:

$$\text{F i } \frac{1}{D} p R_T^2 \frac{A_0^2}{2 r_0 c}, \quad E \text{ ? } \text{F}\, t_D. \quad (17)$$

As for the considered values, the product $\text{F}\, t_D$ does not exceed the first units of kJ and then under the technical calculations more attention should be paid to calculations by the formula (12). As previously determined, $E > 3$ kJ.

2. EXPERIMENTAL EQUIPMENT AND DIAGNOSTICS

The above estimates were taken into account when creating a elastic pulses generator in the liquid, the main element of which is the plasma gun. The generator electrical circuit diagram is shown in Fig. 1,a, its arrangement at the well mouth is illustrated in Fig. 1,b, and the appearance of the generator discharge chamber is shown in Fig. 1,c.

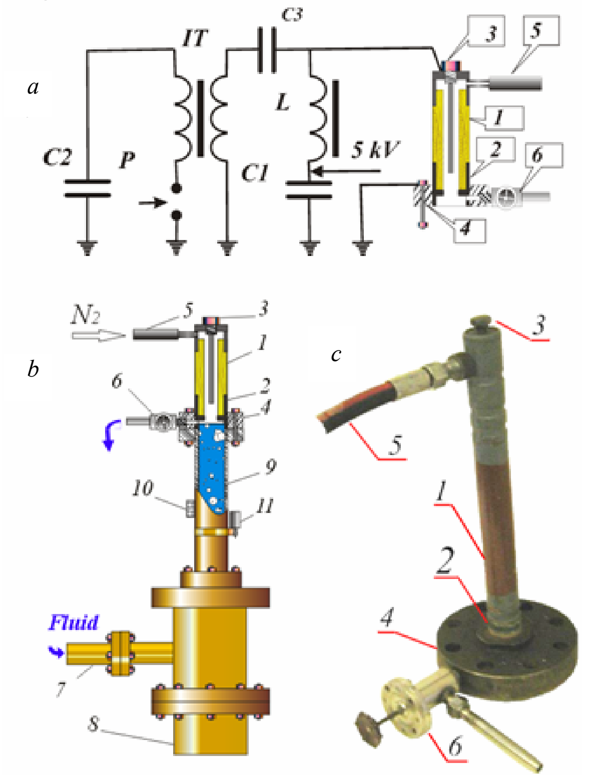

Fig. 1. Elastic pulses generator: a) an electronic circuit diagram; b) the instruments allocation scheme at the wellhead; c) the appearance of the plasma gun

The discharge chamber plasma gun is made of thick-walled insulating pipe 1 with two electrodes: the ring 2 and core 3. The diameter of the dielectric channel is 8 mm, interelectrode distance ~ 8 cm. Accelerator electrodes 2 and 3 are connected in parallel with the energy storage ***C1*** through the nonlinear separating inductance ***L*** - magnetic key.

The operating voltage and capacitance of energy storage – 5 kV and 1.80 mF, discharge duration was ~ 0.5 ms. Thus, the condition (12) and (13.1) are satisfied.

The magnetic key is the inductance L of 20 turns of copper wire wound on a toroidal permalloy core with inner and outer diameters of 10 and 25 cm, respectively, tape thickness – 0.05 mm, width – 3 cm. A initiating high-voltage pulse formed at the discharge capacitor ***C2*** to the primary winding of the pulse transformer ***IT*** after actuation of controllable discharger ***P***. Pulse transformer, with the number of coils in the primary and secondary windings of the 1/16, was made on the same ferromagnetic core used in a magnetic key. High-voltage pulse was applied to the electrode gap through the capacitor ***C3***.

The more detailed description of the generator is given in [23], and electrical characteristics - in [24].

Plasma gun is hermetically connected through the electrode 2 with a standard flange 4 by wellbore equipment. Working gas came in the chamber top from the input electrode 3 through high pressure hose 5. A surplus of gas, borehole fluid degassing products and fluid is evacuated through the hole in the flange 4 and the valve 6 into the atmosphere. In the wellbore liquid operating pressure (wellhead pressure) is provided by fluid feeding through the pipe 7 into the acoustic tube – well 8. The pump-compressor pipe segment 9 is situated between the well head and the plasma gun. The piezoelectric transducer 10 and electrodynamic seismic sensors 11 type GS-20DX is placed on the segment 9. The piezoelectric transducer 10 was used to determine the radial PCP displacement, which is proportional to the pressure perturbations in the liquid, and wellhead vibrations are registered by means of seismic sensors 11 in the vertical direction. These vibrations are excited by hydrodynamic pulse under moving from PCP into big-diameter pipe. The sensors signals are fed to a line-in sound card, which acts as the ADC. The signals are recorded and processed using the software «PowerGraph».

3. THE MEASUREMENT RESULTS AND THEIR DISCUSSION

Under experiments there were found regimes when incoming from the piezoelectric transducer 10 signal was a solitary pulse, the characteristic shape of which is shown in Fig. 2. This signal indicates that the plasma formation (plasmoid) ejected from the gun into the liquid generates a solitary elastic quasi-sinusoidal pulse in the well. The first half-cycle pulse is caused by the expansion of the plasmoid when current flows through it. The processes of recombination and heat transfer in the plasmoid plays a main role after that the discharge current is broken. By reason of that a depression pulse appears in the liquid (note that in computer simulations [16] it was considered only the processes that lead to compression pulse).

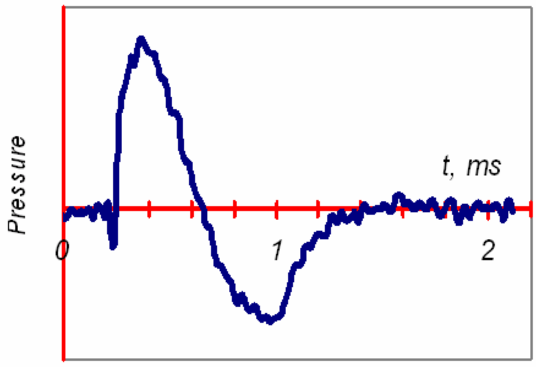

Fig. 2. Elastic pulse pressure

Fig. 3 gives a representation of the frequency spectrum of the excited oscillations. This figure shows that oscillation spectrum is continuous and has the most intense components whose frequencies lie between 0.1 and 1.5 kHz.

Thus it is achieved the frequency conditions (13.1) which are needed for vibration-wave impact on the BHZ [19].

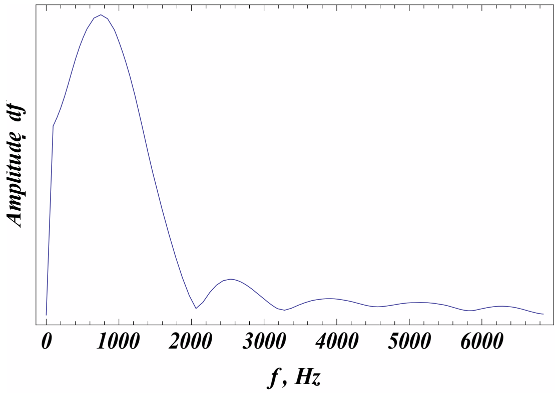

Fig. 3. Spectrum of elastic pulse

Interesting to note that at the compression stage the maximum pressure depends on the input energy, and the wellhead pressure. The first of these relationships is illustrated in Fig. 4, on which the abscissa is the voltage U on the energy storage, and the vertical axis is the pressure maximum A_{pz} in relative terms. The measurements were performed at p_0=25 atm. It is noted that solitary pulses have not appeared under voltage U J 2.5 kV.

Fig. 4 confirms the validity of condition (12). Indeed, according to Figure 4 the minimum value energy of capacitive storage is of the 5.5 kJ, and the calculation by formula (12) gives a value of 2.5 kJ. This energy value indicates on the validity of the condition (12). It should be noted that the comparison does not take into account the residual voltage of energy storage.

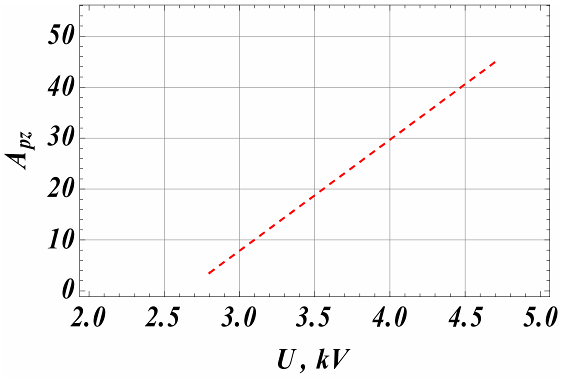

Fig. 4. Dependence of hydro pulse pressure maximum from voltage on energy storage

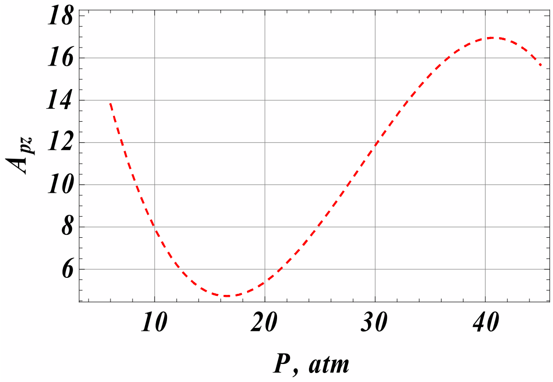

Fig. 5. Dependence of pulse pressure maximum A_{pz} on wellhead pressure P

The second pressure maximum A_{pz} dependence from wellhead pressure P is more complicated, as shown in Fig. 5. These data were obtained when the storage voltage U was U = 4 kV.

It can be suggested that the nature of this dependence is caused not only by the pressure P, but also by the gas bubbles presence in the fluid.

Using piezoelectric transducer observation of the hydro pulse reflected from the bottom hole is very difficult. Therefore, it is advisable to register liquid disturbances by means of using the more sensitive seismic sensors 11 (Fig. 1,b) which registers vibration of the well head. The record of such oscillations under hydro pulse generation is shown in Fig. 6. So as the wellhead is enough complex structure, the waveform displacement of the wellhead has a form different from the decaying sinusoid.

It should be noted that the results presented here were obtained at the oil well number 42 Yaroshivskogo deposit of Priluky NGDU. The depth of the well was 4200 m, operational column had a diameter of pipes: 393.7 mm in depth from 0 to 2200 m, 295.3 mm at a depth of 2200 to 2610 m, 215.9 mm at a depth of 2610 to 4200 m.

Because of the well design the waveform was obtained by recording the signal from the seismic sensor 11, on Fig. 7 the finish part of waveform is shown (initial part of this waveform is shown in Fig. 6).

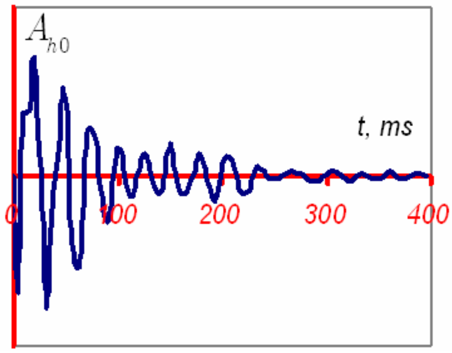

Fig. 6. Waveform of well head displacement due to the generation of hydro pulse

As follows from this figure, at the hole mouth the registration time of the waves reflected from the transitions, i.e., peaks A_{h1}, A_{h2}, is equal to the propagation time of the respective distances (peak A_{hZ}) with the elastic wave velocity in water (1450 m / s). It should be noted that the peak heights A_{h1}, A_{h2} и A_{hZ} are in two orders smaller than the oscillations amplitude A_{h0}.

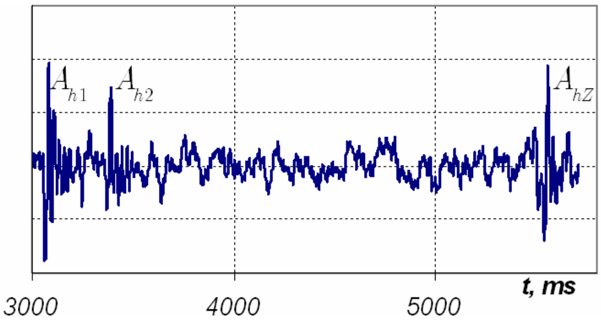

Fig. 7. Waveform of well head displacement due to the reflected hydrowaves

It should be noted that these peaks A_{h1}, A_{h2} and A_{hZ} were recorded only after realizations of several dozen of plasma gun actuations. Furthermore, it should also point out that with the growth of gun actuations number, a gradual increase of the oscillations amplitude is revealed.

Thus, it can be suggested that multiple discharge initiation contributed to the reduction of gas content in the well fluid.

The advantage of continuous signals A_{h0}, A_{h1}, A_{h2} and A_{hZ} registration is that the measuring device is not immersed in well bottom and for the A_{h0} and A_{hZ} signals we can estimate the impulse that well bottom gets from the reflected hydro pulse. This statement is based on the dependence (15) and the independence of the D coefficient on the direction of wave propagation. It should also be noted that the pressure pulse have an impact on the wellhead during several microseconds. The wellhead natural period is ~ 30 ms according to Fig. 6, that is, this is an impact shock. Then relation between the oscillations amplitude of the wellhead and hydro pulse impact shock can be considered linear.

It is easy to then if the wellhead is placed mentally into well bottom then the amplitude of the wellhead oscillations is:

$$A_Z = \sqrt{A_{h0} \text{Ч} A_{hZ}}\,. \tag{18}$$

This relationship (18) and results of oscillations registering which are similar to those in Fig. 6 and 7 allow to establish the dependence of the impulse kA_Z on the hole bottom and wellhead pressure P. The results of this experimental data analysis are presented in Figure 8. In this figure, the vertical axis plotted in dimensionless units of the impulse kA_Z transmitted to well bottom by elastic wave. These data were obtained when the storage voltage was $U = 4$ kV too.

It is interesting that pressure P range of highest values kA_Z coincides with such range P at which, according to Fig. 5, there are smallest values of amplitude A_{pz}.

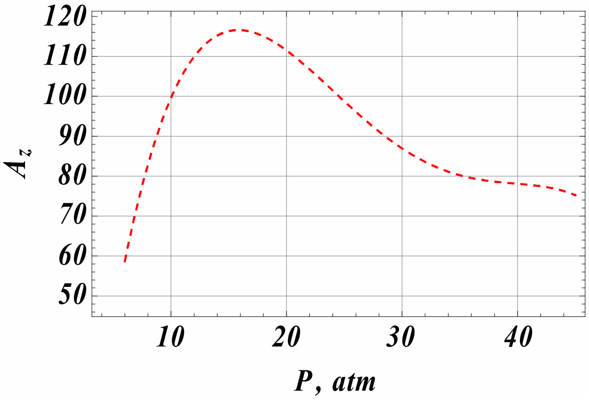

Fig. 8. Dependence of impulse kA_Z, which transmitted to well bottom from elastic wave, on wellhead pressure

Possibly the reasons for this fact are the nonlinear properties of two-phase fluid and the spectra of elastic pulses. Both of these reasons are related to the magnitude of the wellhead pressure. Under the acoustic waves propagation in two-phase fluid the waves are transformed into the shock waves [19], which is known to have a strong damping.

The analysis of Fig. 8 shows that the impact on the BHZ by the proposed method it should preferably carry out when the wellhead pressure lies in range from 10 to 25 atm. It is especially necessary to note that after the described above experiment series with plasma gun, which consisted of 87 elastic pulse excitations at well mouth, the oil production was changed.

That is, before a acoustic impact the well production rate was 0.04 ton/day, and after the acoustic fields generation the production became 119.7 tons of oil and 7.19 m^3 of gas during the next 63 days, according to the measurements of NGDU specialists.

The acoustic field generation by means of the described method is usually accompanied by an increase in production rate in other wells.

CONCLUSIONS

The described above results lead to the following conclusions and permits to point out the direction of further researches.

The proposed method of acoustic field generation by means of a plasma gun which located at the well mouth is put into practice with a good outcome.

This indicates the validity of the proposed criterion (12) for the development of analogous solitary acoustic pulses generators.

The measurements results indicate that the value of the wellhead pressure is one of the most important parameters which affect on such quantities as the amplitude, the shape and the attenuation of the generated hydrodynamic pulse, as well as on the intensity of the acoustic impact on the well bottom. The corresponding dependence is illustrated by experimental data.

The optimal wellhead pressure range was determined.

It is demonstrated that acoustic fields generated by this method can positively affect on the subsequent process of oil production.

However, the results point to the need of the following actions.

At first, it is needed to clarify the nature of the effect of gas bubbles in the liquid on the plasmoid expansion.

The second, for the practical application of the method (oil well productivity stimulation) it is necessary to determine the applicability conditions, as well as the duration or the multiplicity of acts impact on the BHZ.

We note especially the arising problem, which follows from the contradiction to increase the pressure (repression) in the well on this method and the experience of submersible hydro-wave generators, whose work is recommended [19] in a depression (decrease bottom hole pressure). The solution of these problems should clarify the mechanisms of acoustic impact which is described in this paper.

REFERENCES

1. Yu.E. Kreindel. *Plazmennye istochniki elektronov.* Moscow: "Atomizdat", 1977, 144 p.
2. Winston H. Bostick. Plasma Motors // *Conference on Extremely High Temperature. Boston, MA, USA. 18-19 March 1958. Edited by Heinz Fischer and Lawrence C. Mansur.- New York.: John Wiley & Sons, Inc.,* 1958, p. 169-178.

3. B.M. Manzon. Uskorenie makrochastits dlya upravlyaemogo termoyadernogo sinteza // *Uspehi fizicheskih nauk*. 1981, v. 134, p. 611-639 (in Russian).
4. W. Witt, M. Loffler. The Electro-magnetic Gun - Closer to Weapon-System Status // *Military Technology*, 1998, № 5, p. 80-86.
5. I.A. Glebov, F.G. Rutberg. *Moschnye generatory plazmy*. Moscow: "Energoatomizdat", 1985, 153 p.
6. N.N. Rykalin, and L.M. Sorokin. *Metallurgicheskie VCh-plazmotrony: elektro- i gazodinamika*. Moscow: "Nauka", 1987, 161 p. (in Russian).
7. R.P. Ouellette, M.M. Barbier and Paul N. Cheremisinoff. *Electrotechnology Vol. 5. Low Temperature Plasma Technology Applications*. Michigan: "Ann Arbor Science Publishers", 1980, 147 p.
8. A.V. Rimskiy-Korsakov, V.S. Yamschikov, V.I. Zhulin, V.I. Rechtman. *Akusticheskie podvodnye nizkochastotnye izluchateli*. Leningrad: "Sudostroenie", 1984, 181 p. (in Russian).
9. K.A. Naugol'nych, N.A. Roy. *Electricheskie razryady v vode*. Moscow: "Nauka", 1971, 155 p. (in Russian).
10. L.A. Yutkin. *Elektrogidravlicheskiy effect i ego primenenie v promyshlennosti*. Leningrad: "Mashinostroenie", 1986, 253 p. (in Russian).
11. O.L. Kuznetsov, E.M. Simkin, Dzh. Chilingar. *Fizicheskie osnovy vibratsionnogo i akusticheskogo vozdeystviya na neftegazovye plasty*. Moscow: "Mir", 2001, 260 p. (in Russian).
12. R.A. Maksutov, O.N. Sizonenko, P.P. Malyushevskiy, etc. Ispolzovanie elektrovzryvnogo vozdeystviya na prizaboynuyu zonu // *Neftyanoe hozyaystvo*. 1985, № 1, p. 34-35 (in Russian).
13. L.Y. Minko. *Poluchenie i issledovanie impulsnyh plazmennyh potokov*. Minsk: "Nauka and tehnika", 1970, 235 p. (in Russian).
14. M.N. Kazeev. Moschnye ablyatsionnye plazmennye potoki dlya tehnologicheskih primeneniy // *Prikladnaya fizika*. 2000, № 4, p. 14-21 (in Russian).
15. Y.E. Kolyada. Generatsiya akusticheskih poley pri inzhektsii plotnyh plazmennyh sgustkov v zhidkost // *Doklady natsionalnoy akademii nauk Ukrainy*. 1999, № 6, p. 91-95 (in Russian).
16. Yu.E. Kolyada, V.I. Fedun. Excitation of elastic pulses by powerful plasmoids in the acoustic waveguide // *PAST*. 2008, № 4, p. 260-263.
17. M.L. Vladov. *Seysmoakusticheskie mnogovolnovye issledovaniya v vodonapolnennyh skvazhinah s pomoschyu elektroiskrovogo istochnika uprugih voln: Atoreferat diss... Doctor Physics and Mathematics Sciences: 25.00.10*. Moscow: Moscow State University. 2003, 49 p. (in Russian).
18. Y.B. Zel'dovich, Y.P. Raiser. *Fizika udarnyh zvoln i vysokotemperaturnyh gidrodinamicheskih yavleniy*. Moscow: "Fizmatlit", 2008, 656 p. (in Russian).
19. V.P. Dyblenko. *Volnovye metody vozdeystviya na neftyanye plasty s trudnoizvlekaemymi zapasami. Obzor i klassifikatsiya*. Moscow: OAO "VNIIOENG", 2008, 80 p. (in Russian).
20. S.M. Gadiev. *Ispolzovanie vibratsii v dobyche nefti*. Moscow: "Nedra", 1977, 154 p. (in Russian).
21. L.D. Landau, E.M. Lifshitz. *Teoreticheskaya fizika, v.6. Hydrodynamics*. Moscow: "Nauka", 1986, 486 p. (in Russian).
22. V.A. Krasilnikov. V.V. Krylov. *Vvedenie v fizicheskuyu akustiku*. Moscow: "Nauka", 1984, 403 p. (in Russian).
23. Yu.E. Kolyada, V.I. Fedun, I.N. Onishchenko, E.A. Kornilov. The use of a magnetic switch for commutation of high-current pulse circuits // *Instruments and experimental techniques*. 2001, v. 44, № 2, p. 213-214.
24. V.I. Fedun, Yu.E. Kolyada, O.N. Bulanchuk, V.V. Garkusha. Electrickie harakteristiki impulsnogo plazmennogo gidroakusticheskogo izluchatelya // *Visnik Donetskogo universitetu. Seriya A: Prirodnichi nauki*. 2000, iss.1, p. 89-92 (in Ukrainian).

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ГЕНЕРАЦИЯ АКУСТИЧЕСКИХ ПОЛЕЙ ПЛАЗМЕННЫМИ СГУСТКАМИ В СКВАЖИНАХ

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В статье предложен метод генерации акустических полей с помощью плазменной пушки. Приведены результаты акустических измерений. Показано, что давление на устье скважины влияет на амплитуду и форму гидроимпульса, его затухание и на интенсивность воздействия в области забоя скважины. Определен интервал давлений на устье скважины, на котором достигаются наибольшие значения импульса силы на забой скважины. Показано, что данный метод может благоприятно влиять на последующий процесс нефтедобычи.

ГЕНЕРАЦІЯ АКУСТИЧНИХ ПОЛІВ ПЛАЗМОВИМИ ЗГУСТКАМИ У СВЕРДЛОВИНАХ

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У статті запропоновано метод генерації акустичних полів з використанням плазмової гармати. Наведено результати акустичних вимірювань. Показано, що тиск в усті свердловини впливає на амплітуду та форму гідроімпульсу, його загасання та на інтенсивність дії на область вибою. Визначено інтервал тисків в усті свердловини, при якому досягаються найбільші значення дії імпульсу сили на вибій. Показано, що даний метод може сприяти істотному збільшенню видобутку нафти.