PULSE ELECTROTHERMAL PLASMA ACCELERATORS AND ITS APPLICATION IN THE TECHNOLOGIES

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The possibility of the pulsed electrothermal plasma accelerator application was shown for some technological problems. In particularly it was demonstrated the possibility to produce colloidal solutions contained metallic particles, the modification of the structural steel surface properties by means of surface Titanium doping, the construction of pulsed electrothermal plasma accelerator as the borehole generator of the elastic pulses and use it for the intensification of the hydrocarbons production.

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INTRODUCTION

The previous article [1] deals with the operation of the erosion pulsed electrothermal plasma accelerator working under atmospheric conditions. It was showed that this plasma accelerator can be used as a multifunctional device for the solution of some scientific problems. In particular it was shown that it is possible to form a high-microsecond electron beam outside vacuum conditions. The beam is shaped in the accelerator discharge channel under action of additional high voltage pulse. The acceleration is produced due to the phenomenon of runaway electrons [2]. It was shown that the accelerator can be used as a reactor for nanoparticle synthesis. The mechanism of nanoparticle formation was established in the electrothermal systems. The nanoparticle production occurs under nonequilibrium condensation of supersaturated vapor [3]. For the first time it was showed the possibility of power acoustic pulses generation by means of the dense plasma injection into liquid [4].

In this article it was shown that the using of pulsed electrothermal plasma accelerator may be possible to resolve some technological problems. In particular it was considered the possibility of the colloidal solution production, the surface properties modification of metals and alloys, the construction on the basis of it the borehole elastic pulse generator and using this generator for intensification of the hydrocarbons production.

1. PRODUCTION COLLOIDAL SOLUTION

It is known that colloidal solutions are widely used in the agriculture for growth stimulation of crops and in medicine and biology. Nanostructured liquids are important component in the machinery construction under finalization of machine elements and units.

For the production of colloidal solution it is used the chemical methods, the methods based on the electrical explosive of conductives, electrolysis phenomena methods. But the mostly perspective methods are the methods which based on using pulse arc discharge in gas or liquid [5] and on using the pulsed electrothermal plasma accelerator. Our development is original in its own way. The reactor for the synthesis of ceramic nanoparticles was created on the base of this development [6]. A distinctive feature of this apparatus is to shape a directed flow of matter which significantly improves its produceability and reduces the loss of the synthesized particles. The possibility to generate the metallic nanoparticles by means of electrothermal accelerator was demonstrated in [1]. It discovers the possibility to use it for the production of nanostructured colloidal solutions. To realize this idea the device was constructed (Fig. 1)

In [1] the device electrical circuit was described. To the right there is the accelerator, where 1 – housing, 2 – rod cathode, 3 and 4 – molded metallic barrels, 5 – anode orifice. In this case the lower part of the accelerator (anode) is immersed in the liquid in which the gas-plasma blob is injected through the orifice 4. Thus the electric discharge evolution is realized not in the liquid medium but in the air. The produced pulse jet of nanopowder is fully injected in liquid and enables to generate the elastic wave which help to mix the components and to form a colloidal solution. There is no loss of material. The stable colloidal solution is formed as result.

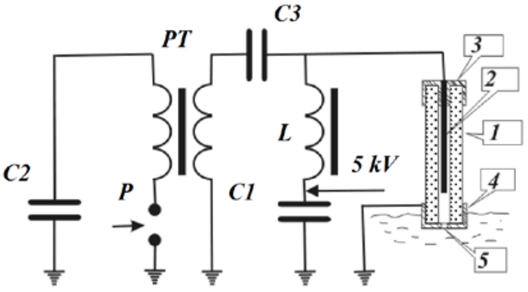


Fig. 1. The installation diagram for colloidal solutions producing

For producing the pure metallic particles of cathode material we used a paper-bakelite body instead of ceramic body which was used in [6]. The main bakelite component is phenol, the decay degree of which can reach up to 80…99% at a low temperature plasma [7]. Its decay occurs on atoms and molecules, and plasma cooling leads to the formation of carbon dioxide – CO_2. In this case the wall material does not contribute to the elemental composition of the synthesized nanoparticles. And their composition is determined exclusively by the electrode material. The formation of nanoparticles takes place in the inert atmosphere of carbon dioxide. This method of colloidal solutions production is protected by Ukraine’s patents [8].

2. MODIFICATION OF METAL AND ALLOY SURFACE PROPERTIES

The pulsed plasma jet are successfully applied to modify the surface properties of metals and alloys [9, 10]. At the same time we can mark out two mechanisms of influence on materials. The first mechanism is hardening due to influence of pulsed heat flux on the metal surface with subsequent cooling. This mechanism works when the cooling rate of heated layers is not less than 10^6 grad/s. The second mechanism is the surface doping of metals and alloys. In this case the doping is caused by the thermodiffusion. If the first method of surface modification is well studied and applied in the technology then the second method is still under research. This method favorably differs from well-known technology of CIB (condensation in combination with ion bombardment). In the case of the doping via CIB the hardening of the surface layer is due to the cathode material and also as a result of the interaction this material with the base material and the formation of solid solutions and chemical compounds - oxides and nitrides. The effect of hardening increases more significantly when using pulse plasma jets, because the surface is under influence of impulse heat and pressure which leads to the refinement of the structure and the formation of new phases. Furthermore under pulse action the coating becomes significantly thicker than under using the CIB. Because of the pulse action of temperature and pressure this method is favorably distinguished from the known method of electric arc facing and plasma-jet hard-facing of details and products. In these methods a work piece can be easily deformed and tempered due to heating up. In this regard it is interesting to investigate the application of the pulse electrothermal plasma accelerator for the doping of structural steels and alloys by metals with good operating characteristics. In [11] the study of the steel 40X surface doping by titanium was discussed.

For this purpose the titanium anode was used in the plasma accelerator. The possibility of 40X steel surface doping by titanium was established. The coating thickness and coating properties are determined by the accelerator operating conditions, in particular, the stored energy and the amount of actuation pulses. The character of microhardness modification is monotonically decreasing function with a maximum value on the sample surface.

Thus when the stored energy was 12 kJ and the sample was acted six times the hardened layer thickness has reached 0.076 mm with a maximum value of microhardness 10510 MPa which decreases monotonically to the value of the base material – 2500 MPa. Besides that we established that increasing multiplicity of action leads to decrease porosity and microcrack density. For this regime Fig. 2 shows a microsection. We can see that the modified layer has a light gray color well-marked on the background of ferrite-pearlite structure of the base metal - steel 40X. It can be seen that titanium diffuses into the sample (transition zone is seen). In the ferrite-pearlite structure of main metal the increase of martensite concentration is observed under approaching to the modified layer (solid solution of titanium α-Fe).

The important results were obtained as the application of X-ray structural analysis to study the behavior of the structural and physical processes occurring after plasma processing the initial sample. The investigations were made on the Dron-3 apparatus. The Cuprum spectral line Kα was studied. The registration was realized with the step of 0.02 grad, X-ray spectral line identification was made under ASTM table in the angle range (20 grad < 2 θ < 90 grad). The diffraction patterns (Fig. 3) show that Osbornite (TiN) and Titanium Nitride (TiN) differed from each other by lattice parameter is observed in the modified layer. The martensite and beta titanium dioxide (TiO_2) spectral lines are visible in the spectrum too.

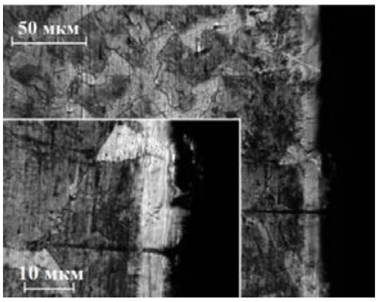


Fig. 2. The microstructure of 40X steel sample

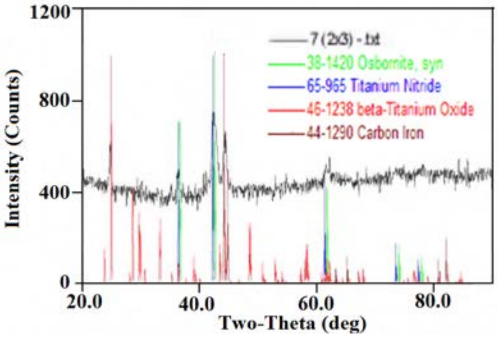


Fig. 3. The diffraction patterns of the 40X steel after Titanium doping

So the using of the pulsed electro-thermal plasma accelerator for the metal and alloy surface dopping can be very perspective method which will substantially improve the operating characteristics of the crusial machinery components, units and elements.

3. CONSTRUCTION OF THE BOREHOLE GENERATOR OF ELASTIC PULSES

The applying of elastic pulses borehole generator is widely used for deep acoustic logging that provides search, identification and quantitative characteristics of minerals, as well as for production intensification of hydrocarbons due to elastic pulses which impact on the bottom hole formation zone.

For vibration excitation it is usually used generators which operate on the electric discharge in liquid. Less frequently it is used solid explosives. In this case the source and capacitive energy storage is immersed to a significant depth which complicates the process ability [12 - 14]. However the small borehole diameter and a number of technological problems do not enable to use the capacitive energy storage with more than kilojoules. It prevents to further increase of elastic pulses power. These restrictions are removed under placing the pulse generator at the wellhead and using the well as an acoustic waveguide. The energy storage is placed enough closely to the vibration source. But the ability to propagate of power elastic pulses into a significant depth up to several kilometers must be investigated. In first time this problem was numerically solved in [15]. In this section the main results of these studies are provided.

3.1. THE NUMERICAL SIMULATION OF WELLHEAD PLASMA GENERATOR OF ACOUSTIC PULSES

As mentioned above the electrical discharge is fired in the accelerator channel and it develops in air. Afterwards the plasmoid is injected into liquid which fills the cylindrical waveguide. In this case it is possible the formation and expansion of a one-dimensional gas-steam cylinder along the waveguide axis.

In this case the gas – liquid interphase boundary will move translationally and excited in the fluid perturbations will form a plane wave.

For the numerical simulation of these processes we make some problem formalization.

Firstly we assumed that the energy loss due to the radiant and electronic mechanisms of heat transfer can be neglected. Indeed if we take into account that the initial linear characteristic dimension x_o of the plasma formation is of the order of one cm and the plasma temperature ~ 10000 K then the thermal diffusivity will have a value of ~ 0.23 cm^2/s [16]. Then the characteristic time τ_T of heat transfer will be approximately equal to $\tau_T \sim x_0^2 \chi^{-1} \approx 4$ s which exceeds the discharge time τ_p by several orders. Consequently in this case the gas-vapor cavity can be considered as a heat insulated homogeneous medium having a sharp boundary with the cold liquid and metallic walls. In the system the power conversion is described by equation [17]:

$$dW + \delta A = \delta E(t)\,, \tag{1}$$

where dW – the change of the gas-vapor cavity internal energy, δA – cavity work above the liquid and $\delta E(t)$ – the energy released in the discharge during the period of time dt.

The internal energy can be approximately determined using the expression for the energy of ideal gas: $W = PV/(\gamma - 1)$ wherein *P*– the pressure and *V*– the volume of the cylindrical vapor-gas cavity, γ – efficient gas adiabatic index value ($\gamma \approx 1.26$). The gas volume is product of the waveguide cross sectional area on the height of the gas cylinder x: $V = S_0 x$. So the internal energy change is

$$dW = \frac{S_0 x dP + P S_0 dx}{\gamma - 1}\,. \tag{2}$$

Secondly the transitional motion of the interphase enables to connect the cave pressure and interphase speed $\vartheta = dx/dt$. From the equality liquid pressure $P_0 + \rho c(dx/dt)$ and cavity pressure P on the interphase we can get

$$P = P_0 + \rho c \frac{dx}{dt}, \quad dP = \rho c \frac{d^2 x}{dt^2}\, dt\,. \tag{3}$$

Then the gas-vapor cavity work is

$$\delta A = PdV = \left(P_0 + \rho c \frac{dx}{dt} \right) S_0 dx\,. \tag{4}$$

Thirdly based on the experimental data [1, 4, 19] we supposed that the electric discharge energy is transferred into the cavity in accordance with the law which is well described by expression:

$$\delta E(t) = \frac{\pi E_0}{2\tau_p}\left(1 - \Theta\left(t - \tau_p\right)\right)\sin\left(\frac{\pi t}{\tau_p}\right) dt\,, \tag{5}$$

where the E_0 is the total energy released in the cavity, t is time, τ_p is discharge time, $\Theta(t)$ is the Heaviside function.

The substitution of the expressions (2, 4, 5) in the (1) with (3) gives the second order differential equation:

$$x \rho c \frac{d^2 x}{dt^2} + \gamma \left(P_0 + \rho c \frac{dx}{dt} \right) \frac{dx}{dt} =$$

$$= \left(\gamma - 1\right) \frac{\pi E_0}{2 S_0 \tau_p} \left(1 - \Theta\left(t - \tau_p\right)\right) \sin\left(\frac{\pi t}{\tau_p}\right). \tag{6}$$

Thus the equation (6) for given initial conditions ($x_0 = x(0)$, $\left.\frac{dx}{dt}\right|_{t=0} = 0$) and the given parameters (P_0, τ_p, S_0 and E_0) allows to determine the law of vapor-plasma cavity expansion.

In addition the solution of this equation under substituting in (3) allows determining the pressure in the cavity, as well as the shape of the emitted pressure pulse.

Below the results of numerical calculations are presented.

The Fig. 4 shows the dependence of the cavity front motion in the well (waveguide) on time $x(t)$ for released energy values 5; 10 and 40 kJ, the initial cavity size = 1 cm and 78.5 cm^2.

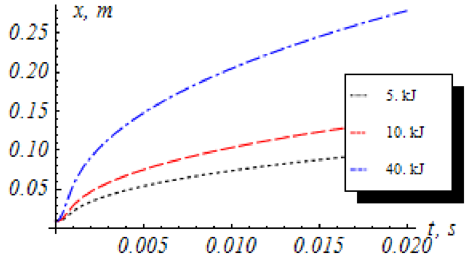


Fig. 4. The dependence of the cavity front motion in the well on time $x(t)$ for various released energy values

The Fig. 5 shows the emitted wave pulses under input energy values 20 kJ and initial cave size x_0 = 0.1; 1; 5 cm and $S_0 = 78.5$ cm^2. It is important to note that in this model the initial gas (air) cavity volume S_0x_0 substantially distinguishes the process of generating elastic pulses by plasmoid from the electric discharge in liquid. If the initial volume of the air cavity tends to zero then by virtue of the correspondence principle the energy release in the liquid is described by the dynamics of the electric discharge in liquid.

The following figures show the pressure amplitude change as a function of the coordinates ζ but not on time. Notably it is not showed pulse width but its length. It should be noted that initial cave volume $S_0 x_0$ makes a considerable influence on the wave amplitude of acoustic radiation.

The results indicate that for increasing the pulse amplitude it has to reduce the initial boundary (i.e. the initial volume of the cavity). However the initial volume threshold is the one that ensures the emitter operation in the linear acoustics regime for the prescribed law of energy input into the cavity which is determined by the following parameters: E_0, τ_p, dE/dt – a rate of energy input. Thus the front speed of the cylindrical vapor-gas cavity or maximum fluid speed dx/dt can not exceed the sound speed in the medium.

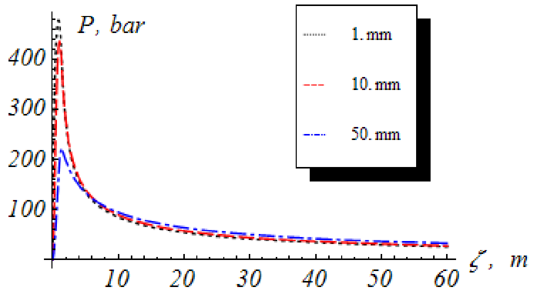


Fig. 5. The pulses of emitted waves under energy of 20 kJ and various initial coordinates

Consequently the use of the thermal plasma accelerator enables to generate power solitary acoustic pulses in the wellbore which amplitude reaches one hundred bar and more.

3.2. NUMERICAL SIMULATION THE PROPAGATION OF POWER ELASTIC PULSES IN ACOUSTIC WAVEGUIDE

An important question is to study the dynamics of propagation of powerful solitary elastic pulses in the well which using as an acoustic waveguide. We studied the decay of intense acoustic pulse propagating in the water-filled well to a considerable depth of about ~10^3 m and more. For this aim the excited pulse was expanded in Fourier series. We supposed that each harmonic decays only with own sound damping coefficient. Since under propagation in the pipe the main part of absorption energy is due to the effect associated with the presence of the wall. Then the acoustic absorption coefficient was taken to be [18]:

$$\gamma = \frac{\sqrt{\omega}}{\sqrt{2}Rc}\left[\sqrt{\nu} + \left(\frac{C_p}{C_V} - 1\right)\sqrt{\chi_L}\right], \qquad (7)$$

where ω – the harmonic frequency; R – the tube radius; ν – the kinetic viscosity coefficient; C_p and C_V – the heat capacity of liquid under constant pressure; χ_L – thermal diffusivity of liquid. After that pulse shape was restored by means of Fourier transform.

The Fig. 6 showed the pulse amplitude-spatial characteristics on the depth 0; 1 and 3 km for various energies which input into vapor-gas cavity.

These results demonstrates that the amplitude values of the pulse is decreased almost in 10 times. However this method provides the generation of significant pressure amplitude even at a depth of 3 km. This amplitude reaches value of 30…100 bar.

Obtained in this section estimates and numerical simulations allow to get the practical realization of the elastic pulses generator and apply it for the intensification of the hydrocarbons production.

4. ELECTROTHERMAL PLASMA ACCELERATOR USING FOR INTENSIFICATION OF HYDROCARBONS PRODUCTION

In this section there are results on the use of pulsed electrothermal plasma accelerator for the intensification of hydrocarbons production. At the same time the increase of productivity and the reanimation of borehole is the result of the elastic pulses impact on the bottomhole formation zone. It is important to note that this technology agrees with Kyoto Protocol concerning environmental requirements for a new technology. The suggested method do not use the pumping of chemicals which applies under hydraulic fracturing. Therefore the intensification of the hydrocarbons production by means of elastic pulses is very promising and lately it is widely used in one or another form. There are known the next intensification methods: acoustic, vibration-wave and seismic. These methods distinguish from each other not only elastic wave characteristics but aftereffects in the productive stratum. The proposed method of the impact on bottomhole formation zone (BFZ) should be considered as vibration-wave method in accordance to the classification of [12 - 14]. According to the author [12 - 24] the main effect of the vibration-wave impact on the influence on the rheological properties of liquids, the increase of the liquid mobility in the stratum, etc.

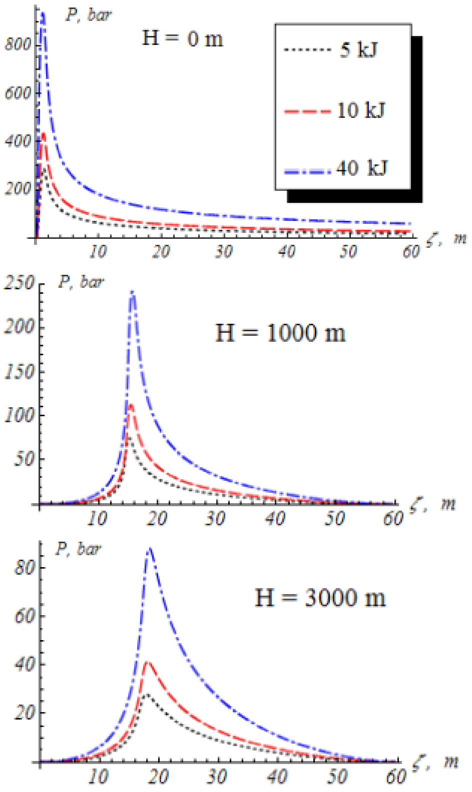


Fig. 6. The amplitude-spatial characteristics on the depth 0; 1 and 3 km for various energies which input into vapor-gas cavity

In [14] it was shown that for the effective impact on the BFZ it is necessary to excite the hydrodynamic pulse in the wellbore with pulse fundamental frequency $f_{0,\max} \approx \left(2\tau_p\right)^{-1}$ which is of the order of kilohertz. The pulse amplitude A_Z should be 10 bar at the well bottom zone (here τ_p – pulse duration).

As follows from the previous section (see Fig. 6) the elastic pulse amplitude can reach 20…90 bar in the borehole on the depth of 3 km. Fig. 7 shows the frequency spectrum of the excited pulse which satisfies the conditions pointed above.

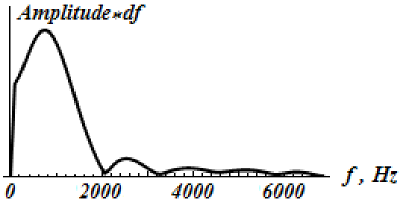
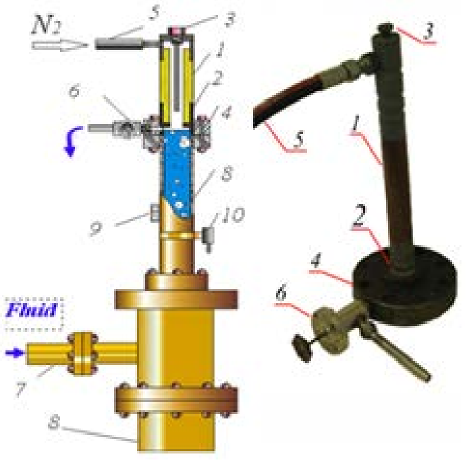


Fig. 7. The spectrum of elastic pulse

The borehole pulses generator was created for this project (Fig. 8). The Fig. 8 shows: 1 is the body of the electrothermal plasma accelerator; 2 and 3 are the ring and core electrode; 4 is the flanged joint; 5 and 6 are the hoses for the compressed air supply and venting; 7 is the pipe for fluid supply into the wellbore; 8 is the wellbore (pump-compressor pipe); 9 and 10 are the piezotransducer and electrodynamic seismometer.



a *b*

Fig. 8. Wellbore generator of elastic pulses: the diagram of connection with the wellbore (a); its appearance (b)

The principle of generator operation is the next. The fluid is pumped through the pipe 7 into the wellbore till it will be completely filled. The compressed air is supplied through the horse 5 that provides the initiation and development of the gas discharge. The generated pulse propagated through the wellbore (the acoustic waveguide) to the well bottom zone (oil staratum) and influenced on it by mechanically. Fig. 9 showed the elastic pulse shape which generated by the plasma accelerator at the wellhead. The Fig. 10 demonstrates the signals which reflected from the borehole pipe reducer (A_{h1} and A_{h2}) and from the oil stratum (A_{hZ}). The measurements were made on the well daylight surface by the sensors 9 and 10. The appearance moment of the peaks on this oscillogram equals to the propagation time of the elastic pulse in forward and reverse directions with the sound speed in water of 1450 m/s.

The measurement results confirm the enabling of elastic pulses excitation in the wellbore by using the electrothermal plasma accelerator and the pulses reach to stratum area. It opens up the possibility to make job on the intensification of hydrocarbons production.

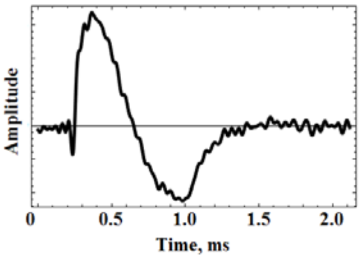


Fig. 9. The pressure change of the elastic pulse in time

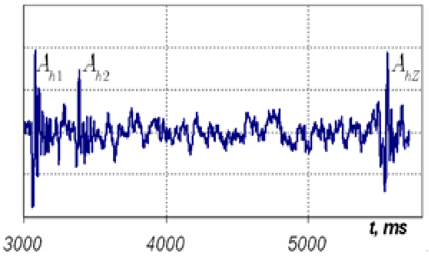


Fig. 10. The oscillogram of the reflected signals

These experiments were made on five oil wells with flow rate which does not exceed 3 tons per day. Their depth is 4 km away. After processing each well in 100 pulses for 2 hours their productivity increased by more than twice. The achieved effect was observed for 3-6 months depending on the nature and characteristics of the stratum structure. The detailed results of our experiments are given in [19, 20]. The proposed method of the intensification of hydrocarbons production is protected by the patent of Ukraine [21].

CONCLUSIONS

So by means of pulse electrothermal plasma accelerator the following problems were solved

1. To produce the colloidal solutions which contain only metallic nanoparticles with chemical composition that is determined by composition of accelerator electrode. The using of paper-bakelite body makes possible to reach it.
2. To realize the modification of structural steel surface properties by means of Titanium surface doping. In this case Osbornite and Nitride Titanium was observed in the modificated layer.
3. To create the borehole elastic pulses generator which is successfully used for intensification of the hydrocarbons production. The elastic pulses act on the productive stratum and the wellbore is used as an acoustic waveguide at the same time.

REFERENCES

1. Yu.E. Kolyada, V.I. Fedun. Pulse electrothermal plasma accelerators and its application in scientific researches // *Problems of Atomic Science and Technology. Series «Plasma Electronics and New Acceleration Methods»*. 2015, № 4, p. 325-330.
2. Yu.E. Kolyada. Pulsed high-current electron beams formed without vacuum // *Technical Physics Letters*. 2000, v. 26, iss. 8, p. 721-722.
3. Yu.E. Kolyada, V.I. Fedun, et al. Formation mechanism of the metallic nanostructures using pulsed axi-

al electrothermal plasma accelerator // *Problems of Atomic Science and Technology. Series «Plasma Electronics and New Acceleration Methods»*. 2013, № 4, p. 297-300.

4. Yu.E. Kolyada. Generatsiya akusticheskih poley pri inzhektsii plotnyh plazmennyh sgustkov v zhidkost // *Doklady natsionalnoy akademii nauk Ukrainy*. 1999, № 6, p. 91-95 (in Ukrainian).
5. I.E. Kareev, V.P. Bubnov, D.N. Fedutin. Electric-arc high-capacity reactor for the synthesis of carbon soot with a high content of endohedral metallofullerenes // *Techn. Physics*. 2009, v. 54, iss. 11, p. 1695-1698.
6. D.R. Peterson, D.E. Wilson. *Method and apparatus for direct electrothermal-physical conversion of ceramic into nanopowder*. United States Patent № 6472632, published on October 29, 2002.
7. A.G. Bubnov, V.I. Grinevich, N.A. Kuvykin. Phenol degradation features in aqueous solutions upon dielectric-barrier discharge treatment // *High Energy Chemistry*. 2004, v. 38, № 5, p. 338-343.
8. Yu.E. Kolyada, P.S. Harlashyn, V.Ja. Antoshko. *Method for preparing of colloidal solutes*. Ukraine Patent for utility model № 92710, 2014.
9. L.I. Ivanov, V.N. Pimenov, V.A. Gribkov. Vzaimodeystvie moschnyh impulsnyh potokov energii s materialami // *Fizika I Khimiya Obrabotki Materialov*. 2009, № 1, p. 23-37 (in Russian).
10. A.D. Pogrebnyak, Yu.N Tyurin. Modification of material properties and coating deposition using plasma jets // *Phys. Usp*. 2005, № 48, p. 487-514.
11. A.P. Cheiliakh, Yu.Yu. Kutsomelya, V.I. Fedun, M.A. Ryabikina. The structure and properties of steel 40 Kh after pulsed plasma processing using titanium electrodes // *Science and Education a New Dimension Natural and Technical science*. 2013, v. 8, p 79-84.
12. I.A. Beresnev, P.A. Johnson. Elastic.-wave stimulation of oil production: A review of methods and results // *Geophysics*. 1994, v. 59, № 6, p. 1000-1017.
13. O.L. Kuznetsov, E.M. Simkin, James Chilingar. *Fizicheskie osnovy vibratsionnogo i akusticheskogo vozdeystviya na neftegazovye plasty*. Moscow: «Mir», 2001, 260 p. (in Russian).
14. V.P. Dyblenko. *Volnovye metody vozdeystviya na neftyanye plasty s trudnoizvlekaemymi zapasami:* Obzor i klassifikatsiya. Moscow: «VNIIOENG», 2008, 80 p. (in Russian).
15. Yu.E. Koljada, V.I. Fedun. Excitation of Elastic Pulses by Powerful Plasmoids in the Acoustic Waveguide // *Problems of Atomic Science and Technology. Series «Plasma Electronics and New Acceleration Methods»*. 2008, № 4, p. 260-263.
16. *Teplofizicheskiy spravochnik*. Moscow: «Vysshaya shkola». 1976, 800 p. (in Russian).
17. K.A. Naugol'nych, N.A. Roy. *Electricheskie razryady v vode*. Moscow: «Nauka». 1971, 155 p. (in Russian).
18. L.D. Landau, E.M. Lifshitz. *Hydrodynamics*. Moscow: «Nauka», 1986, 486 p. (in Russian).
19. V.I. Fedun, Yu.E. Kolyada, O.N. Bulanchuk. Acoustic Fields Generation by Plasmoids in the Wellbores. // *Problems of Atomic Science and Technology. Series «Plasma Electronics and New Acceleration Methods»*. 2013, № 4 (86), p. 333-339.
20. www.dgl.dn.ua
21. Yu.E. Kolyada, V.I. Fedun, et al. *Method effects on the bottomhole zone*. Ukraine Patent for utility model № 62300, 2011.

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ИМПУЛЬСНЫЙ ЭЛЕКТРОТЕРМИЧЕСКИЙ ПЛАЗМЕННЫЙ УСКОРИТЕЛЬ И ЕГО ПРИМЕНЕНИЕ В ТЕХНОЛОГИЯХ

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Показана возможность использования импульсного электротермического плазменного ускорителя для решения ряда технологичных задач. В частности, рассмотрены возможности: получения коллоидных растворов, содержащих металлические наночастицы; модификации поверхностных свойств конструкционных сталей путём поверхностного легирования титаном; создания на основе импульсного электротермического плазменного ускорителя скважинного генератора упругих импульсов и использования его для интенсификации добычи углеводородов.

ІМПУЛЬСНИЙ ЕЛЕКТРОТЕРМІЧНИЙ ПЛАЗМОВИЙ ПРИСКОРЮВАЧ І ЙОГО ЗАСТОСУВАННЯ В ТЕХНОЛОГІЯХ

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Показана можливість застосування імпульсного електротермічного плазмового прискорювача для вирішення низки технологічних завдань. Зокрема, розглянуто можливості: одержання колоїдних розчинів, що містять металеві наночастинки; модифікації поверхневих властивостей конструкційної сталі шляхом поверхневого легування титаном; створення на базі імпульсного електротермічного плазмового прискорювача свердловинного генератора пружних імпульсів та його використання для інтенсифікації видобутку вуглеводнів.