

Effectiveness of the Powerful Methods of Oil and Gas Production Intensification and Prospects of Their Application for Unconventional Collectors

UDK 622. 245. 3. 5: 622. 276. 66

© Y.I.Voytenko

Dr. of technical sciences of UkrDGRI

Analyzed of world experience using modern technologies explosive intensification of oil gas output, pulse and stationary hydraulic fracturing. The prospects of using pulsed counterparts of hydraulic fracturing to extraction unconventional resources is shown.

Key words: explosive technologies, stimulation, oil, gas, fracturing, unconventional resources

The efficiency of oil and gas extraction is inextricably linked to the development and application of the advanced methods of intensification of reservoir fluids inflow. Recently, this problem has become even more urgent in view of the necessity of involvement of unconventional oil and gas reservoirs in the development. All progress in the course of development of the gas shale rock deposits in the U.S. and other gas pools in the world is associated with the use of one of the methods of oil and gas extraction intensification, i.e. layer hydraulic fracturing (LHF) in horizontal wells (HW). The main factor hindering the global spread of this technology is the need to use the large amounts of water mixed with chemical additives posing a danger to the environment and groundwater.

While the main concern of conventional collectors is preservation of reservoir properties (pore and fracture permeability) during the primary and secondary disclosure, fluid permeability restoration in the damaged contaminated zone around the well after the initial disclosure, for unconventional (dense, gas shale rock) deposits it is the increase of the collector fluid permeability by establishing the new drainage channels, i.e. macro or micro cracks [1-5]. The purpose of this paper is to analyze the efficiency of the powerful advanced technology for intensification of oil and gas extraction capable of competing with LHF and to evaluate the possibility of their use for gas production from unconventional reservoirs.

This article examines the physical and combined methods of the oil and gas extraction intensification, including:

new methods of layer torpedoing;

pulse layer fracturing with a powder charge, generator drills, or fuel and oxidizing mixtures (FIM);

explosive and chemical methods (explosion or combustion in the environments of chemically and physically active fluids which filled the vertically or obliquely-directed well).

It should be noted that the experts in hydraulic fracturing find the layer fracturing to be the best of all current technologies of the oil and gas extraction intensification [6-8]. Indeed, the LHF cracks not only have the largest size (~ 20-200 m) [6, 9], but are also maintained in the open position with proppant agent, which is injected into the crack developed in the reservoir together with the fluid. The LHF cracks permeability exceeds the reservoir permeability by several orders. The ratio of the reservoir fluid consumption through a crack $q(2\delta)$ 25 wide vs. the consumption through a porous layer $q(k, h)$ is determined by the formula $q(2\delta)/q(k, h) = (2\delta)^3/12kh$, where k is the permeability of the reservoir, and h is layer thickness. In the case the crack N is $q(2\delta)/q(k, h) = N(2\delta)^3/12kh$. Simple calculations show that the fluid consumption through a crack, for example 0.5mm wide, will be 8,333 times greater than for the layer with a capacity of 1m and permeability of 10-2 mcm².

During the past 40 to 60 years the advanced technological countries of the world developed the pulse analogues of LHF and blasting methods for intensification of oil and gas extraction. The first group includes the solid fuel thermal processing technology with the slowly burning charges or liquid combustive-oxidizing mixtures. The second includes the different methods of the layer pulse hydraulic fracturing using the fast burning modern powder pressure generators, POS, perforator generators, and modern methods of layers torpedoing. The technology represented by this group of methods is characterized by higher pressures, which are usually higher than the threshold pressures of hydraulic fracturing, shorter load pulses and can form from one to several cracks in the layer [1-4].

The effectiveness of explosive intensification methods of oil and gas extraction was studied based on the results of torpedoing and pulse breaks of oil, oil and gas, gas and injection wells of Ukrnafta PJSC, Ukgazvydobuvannia PJSC, some mining companies in Russia, USA, China, Kazakhstan, and Vietnam [1-4]. The research results are presented in table containing the data to compare the efficiency of productive strata fracturing in wells of UkrNafta PJSC, U.S. and USSR [6-8]. The table adopted the following legend: E is specific energy transmitted into the formation during combustion or explosion; k_n are the voids of the reservoir rock.

The data analysis shows that the powerful LHF is not the most effective method of intensification of oil and gas production. Its successful competitor is the pulse layer fracturing (PLF) using GOS and its less powerful types, i.e. special techniques of torpedoing, gap formation by pressure generators, perforator generators. We believe that the residual crack opening with PLF and reservoir rock is ensured not only high pressure and deformation of crack walls, but also by the partial burnout of organics in the reservoir rock and reservoir fluid (oil or condensate) in case of a positive oxygen balance of the combustion products, thermal destruction of the reservoir rock on the crack walls and influence of the atomic hydrogen on the rock, but also by the high layer energy [2]. Besides, the table data analysis shows that:

the efficiency of the blasting methods is increased with increase of the specific energy E transferred to the layer during the device explosive effect (torpedo, pressure generator, POS charge, etc.);

the average efficiency of the most powerful pulse method of the layer fracturing is one and a half to two times higher than that of the other pulse technologies.

The maximum pressure developed during the POS, powder charges and rocket fuels combustion in pressure generators, perforator generators, and during detonation of charges in the dashboards is usually greater than the pressure which can be implemented by the modern PLF technology. This is especially true for large depths ($H > 4000$ m). The crack size is determined by the total energy of the charge and the time of the overpressure effect of the combustion products or wave processes, not to mention the economic component of application of the methods for intensification of oil and gas production. While the share of work for intensification of oil and gas flow for conventional collectors is $\sim 0.1-1\%$, for unconventional collectors it reaches 25% of the total cost of works [5]. Meanwhile the cost of the PLF work exceeds the cost of its pulse counterparts by an order.

The environmental comparative analysis of PLF technology and its pulse counterparts is also disadvantageous for PLF. The first case requires the large volumes of water with chemicals, and the second provides for the products of combustion and explosion, which consist mainly of oxides of nitrogen, carbon, water and atomic hydrogen. However, we need to answer the basic question, is it possible to use the PLF pulse counterparts to intensify the gas production from unconventional reservoirs? The main problem during the break of an unconventional reservoir is to maintain the crack edges in the open state or retain the residual crack opening chemically. The increased permeability of the tight sandstone with a filtration combustion and diffusion of atomic hydrogen requires the additional study and experimental verification in vivo.

Summary data on the effectiveness of explosives and pulse technology in production and injection wells

Method description	Magnification of discharge by oil, Min-max (average)	Magnification of discharge by gas, Min-max (average)	Reception increase	E , MJ/m	k_n , %	Collector rocks
Dilatation layer torpedeing	1, 8 -374 (1, 8 -3)	1,5-16 (2-7)	3, 2 -7 7	6-20	5-25	Terrigenous, carbonate (low-, medium-permeable)
Powder layer fracturing	1.5-∞ (2-3)	-	-	8-40	9-25	- "-
Processing with complex devices (perforator generators)	0 - ∞ (3)	-	-	8-10	3-26	- "-
Pulse layer fracturing with POS	1,25 - ∞ (3-5)	0 - ∞ (3-8)	-	50-85	4-25	- "-
Powerful PLS	1.5-∞ (3-5)	0 - ∞	5-10	-	-	- "-

Not a bad illustration of the possibilities of pulse techniques in reservoirs with the properties close to the dense is the result of intensification of oil production with POS charges at deposits in Lithuania, which obtained the 1.25 to 3.9 times increased debit of wells. The reservoir layer, i.e. the medium Cambrian deposits, is represented by the strongly compacted quartz sandstone with the porosity of 4.1 to 10.2% [1]. The powder generators and POS charges are recommended by developers for collectors with clay content <30% [1]. It goes about the conventional collectors, usually with a rather high formation pressure. Some positive results have been obtained in the reservoirs composed of dense clay with AVPT zones [1].

The main types of unconventional reservoirs are tight sandstones, shales, coal layers and surrounding rock. According to [10], these are dense alevritic-sand collectors of the central basin type of the black shale formation of Sribne DDD depression, lower coal black shale deposits in the northern outskirts of Donbass and in the eastern segment of the northern edge of DDD etc. Each facility requires an individual approach taking into account the physical and mechanical properties of rocks, layer energy, as well as selection of equipment and technology.

Due to the issue of oil and gas capacity of the great depths there is an issue of low-porous sand collectors condition expansion and intensification of oil and gas reservoirs at depths exceeding 4,500 m. The analysis of the results of dozens of completed wells in DDD fields shows that at depths of 3,100 to 5,580 m the best drills, including the charges of foreign production for deep penetration are often ineffective, and they formulate the conclusion as follows, "Poor allocation of water, condensate or natural gas", "Impervious collector" or "dry." In fact, at depths exceeding 5 km the granular oil and gas collector in the traditional sense becomes a tight collector. In the absence of well-developed fractures in the productive interval it is hard to obtain the cost-effective productivity of wells even by applying the advanced disclosure technology, i.e. drilling during the depression, use of the superdeep perforation etc.

For these reservoirs and depths the special techniques and PLF technology or pulse counterparts should be used, as well as the latest disclosure technology and their design methods which would enable to determine the size of cracks fracturing or pulse division, their orientation in space, which depends on the distribution of the principal components of the rock pressure, the number of PRI cracks, their fluid permeability in the presence or absence of propan therein etc.

Thus, the article shows that the effectiveness of pulse layer fracturing techniques with conventional collectors, especially high-energy, is no worse than the effectiveness of a powerful PLF, and has all the prerequisites to address the intensification of oil and gas production from unconventional reservoirs of individual types by adapting the known pulse technologies to these new objects, particularly at great depths.

List of References

1. **Dudayev S.A.** Gas dynamic method of affecting the by-well area of layers to increase their oil output / S.A. Dudayev, V.I. Pavlov // Karotazhnyk. - 2010. – No. 1. - P. 15-45.
2. **Shcherbyna K.G.** Chemical and physical basis of the high-temperature impact on the well bottom zone with water reacting composites: abstract of the thesis ... Doctor of technical sciences / Shcherbyna Karina Grygorivna, Ukrainian Oil and Gas Institute OJSC. - K., 1999. - 34 p.
3. **Mykhalyuk A.V.** Protection of casing strings during the explosive works in wells / A.V. Mykhalyuk, N.A.

Lysyuk. - K.: Vipol CJSC, 2009. - 279 p.

4. **Voytenko Y.I.** Explosive and impulse methods for intensification of oil and gas extraction / Y.I. Voytenko, V.D. Kukshinov, I.V. Lobanov, A. Drachuk // Karotazhnyk. - 2005. - Vol. 3-4 (130-131). - P. 68-80.
5. **Axelrod S.A.** Gas extraction from clay shale (based on the foreign printed articles) // Karotazhnyk. - 2011. - Vol. 1 (199). - P. 80-110.
6. **Gadiyev S.M.** Impact on the bottomhole zone of oil wells / S.M. Gadiyev, I.S. Lazarevich. - Moscow: Nedra, 1966. - 180 p.
7. **Kachmar Y.D.** The use of powerful hydraulic fracturing in the fields of Ukraine / Y.D. Kachmar, A.B. Merkuryev, F.M. Burmych, V.M. Savka // Oil and gas industry. - 1999. - № 4. - P. 28.
8. **Kachmar Y.D.** Methods of designing the hydraulic layer fracturing / Y.D. Kachmar, V.V. Tsiomko // Oil and gas industry. - 2005. - № 4. - P. 12-15.
9. **Krasnikov S.Y.** Analysis of results of testing of the method of hydrodynamic stratification of the main hard-to-break rock in terms of the mine // Interaction of mechanized timbers with lateral rocks. - Novosibirsk: USSR Academy YHD CO, 1987. - Vol. 45. - P. 53-61.
10. **Lukin O.Y.** Hydrocarbon potential of Ukraine and the main directions for its development // Drilling. - 2009. - No. 4. - P. 24-32.

Article Author



Voytenko Yuriy Ivanovych

Doctor of technical sciences, engineer researcher. Main directions of scientific activity - technology and engineering of the secondary disclosure of productive horizons, oil and gas extraction intensification technology, rock and geological material breaking.