Evaluating the technological effect of a horizontal hydraulic fracturing

L V Petrova and V V Buravov
Ufa State Petroleum Technological University, Branch of the University in the City of Oktyabrsky, 54a, Devonskaya St., Oktyabrsky, Republic of Bashkortostan, 452607, Russian Federation
E-mail: larisa_petrova@mail.ru

Abstract. The paper analyzes the technological effect of horizontal hydraulic fracturing. Hydraulic fracturing is understood as a mechanical stimulation method where rock is fractured along the planes of minimal strength as a result of action from fluid injected into the formation.

1. Introduction
All the phenomena and processes in the oil and gas industry are interrelated and interdependent. Some of them are in direct relations, other are connected with indirect links. Thus, an important methodological issue in analysis is studying and measuring the influence of various factors onto the value of studied indicators.

The largest global oil and gas companies are constantly looking for ways to increase efficiency, including by means of innovations in exploration, prospecting and production of oil. Under such conditions, competitiveness and (in the long term) survival of Russian oil companies depends on efficiency of their innovative activities. Currently, extensive use of horizontal wells at deposits with various geological structure in West Siberia determined a necessity to develop accurate techniques allowing for determination of design, applicable stimulation methods and conducting accurate and easy studies with bottomhole apparatuses.

2. Materials and methods
Materials used for horizontal formation fracturing include process fluids and particulate fixative agents. Process fluids are divided into breakdown agents, sand carriers and displacing fluid according to their function. They may be water- or hydrocarbon-based. According to traditional methods of hydraulic fracturing, the crack is completely filled with a propping agent that keeps it open to preserve the fluid ingress path. A new method of hydraulic fracturing creates a network of open channels passing through the propping agent-created stuffing, thus increasing the conductivity of the crack several-fold. Application of this method significantly increased the economic efficiency of wells at several deposits under active development. Hydraulic fracturing (HF) that is, creating an artificial crack inside the productive formation by means of injecting a viscous liquid with a propping agent inside the well is currently one of the main stimulation methods applied to hydrocarbon production. The term horizontal is used for the sake of brevity, to distinguish it from a commonly used HF, which is usually performed...
vertically, and where orientation and propagation angle of the crack being formed completely depends on internal pressures in a given part of the Earth's crust [1, 2].

3. Results and Discussion
The last 30–40 years saw a wide application of directional multistage HF to oil and gas deposits of the US, Canada and Russia existing in various subsurface conditions. During this type of HF, large quantities of sand (500–1000 tons) are injected underground. HF with large amounts of sand allows:

First, filling a large volume of cracks (effectively forming an artificial highly permeable formation inside low permeability rocks) in the nearfield.

Second, a large amount of sand in the nearfield ensures lower contamination of production well walls.

Third, a large amount of sand provides high permeability for hydrocarbons (oil, gas) by means of increasing the area of the HF cracks. Besides, the large amount of sand during the HF allows increasing the productivity of wells and recoverable oil and gas reserves.

The main disadvantages of HF are mutually related and are small thickness of productive formations and almost irreversible penetration of crack tips into the areas of water and oil-and-gas contact (OWC и GOC). Such penetration often leads to fast water intrusion and/or blowby. It is evident that the most optimal location of the HF crack would be in the plane of the productive formation, giving the whole area of the crack a possibility to participate in HC filtration, multiplying the probability of crossing paleocracks (mainly vertical, in accordance with the lines of action of maximal stress in the rock) [3, 4].

At the same time, under complex lithological conditions with alternating deposition and interfingering sublayers it is sometimes desirable that the HF crack opens all the productive layers (Figure 1, Figure 2) while being more flat-lying, for example, at an angle of 45 degrees to the vertical, to prevent the crack from reaching the OWC zone. Multitude of existing well conditions spurs to the necessity of developing a new HF type with controlled slope of crack propagation that is going to become a prevailing tool among advanced recovery methods (ARM) at deposits after a successful completion of its pilot run [5].

The main complication is in ensuring location of the HF crack within the desired plane, as well as volatility of direction of the sum stress vector in the rock; this vector is usually decomposed into one vertical and two horizontal components. Equipping the bottomhole assembly with a necessary set of process and geophysical sensors will facilitate identification of geomechanical properties of the lithological section immediately during the drilling [6].

The second important factor that impedes formation of horizontal HF cracks is that at depths exceeding 600…800 meters, vertical stress (geostatic pressure) is usually much larger than any horizontal stresses. As a result, if no special structural or process measures are taken, the HF crack will be tending to a vertical position. Several methodological models have been developed for developing a deviation of the HF plane away from vertical; they may be used separately or together to maximize their effect.
Figure 1. Horizontal drilling, hydraulic fracturing.

Figure 2. Horizontal hydraulic fracturing.

The third mandatory condition for controlled slope of crack propagation is the necessity to locate the trajectory of this segment of the well in the proposed plane of formation fracturing (that is, horizontal fracturing is impossible to attain with a vertical well) [7].
Other problems follow from those stated above: the height (gap) of the crack opening displacement in this case will be somewhat smaller, leading to shorter and narrower fracture wings (with all other HF conditions being equal, namely, pressure and proppant injection rate) [7]. Conditions of proppant penetration into the gap and filling the crack deteriorate, while subsequent closure pressure will be significantly larger, influencing the residual gap and increasing the strength requirements to proppant. Additionally, there is a probability of stopping the growth of the horizontal crack if its width is less than an existing vertical paleocrack (stress concentrator breakaway) [8].

Principal advantages of the horizontal HF are reduced probability of fast water encroachment and maximization of profit due to additional volumes of oil and gas (Figure 3). Calculations show that if we factor in the costs for subsequent cement squeeze, separation and recovery of formation waters with accounts for power, equipment and service costs (without a 100% guarantee of success), then the horizontal HF shows a large advantage. [9-11]

4. Conclusions.
If we combine more optimal production condition of high-viscous oils, maybe even including development of deposits of notorious Bazhenov formation, it becomes evident that this is the future of technology, while maybe not excluding some alternatives.

1. Modeling of hydraulic fracturing in a horizontal well does not account for a unique stressed state of rocks in the near-wellbore zone.
2. Independent of orientation and azimuth of the wellbore, there is a general trend of initiating the crack along the wellbore wall in case of formation completion.

In addition, the process of the horizontal HF is 20...30% more expensive; its competition here are a regular multistage mini-HF and sidetracking from branched well according to Level 6 TAML.

References
[1] Almukhametova E M, Fattakho D I and Zakirov A I 2018 The efficiency analysis of applying hydraulic fracturing of formation at AB1-2 facility of Potochnoye field IOP C. Ser.: Earth Env. 194(8) 082002
[2] Akhmetov R T, Mukhametshin V V and Andreev A V 2017 A quantitative assessment method of the productive formation wettability indicator according to the data of geophysical surveys SPE Russian Petroleum Technology Conf. (Moscow: Society of Petroleum Engineers, 16-18 October 2017) p 12
[3] Suleimanov R I, Gabdrakhimov M S, Khabibullin M Y, Zaripova L M and Vasilyeva E R 2018 The study of hydraulic hammer device in drilling tool assembly in hydraulic rotary drilling Int. J. of Engineering and Technology 7(2) 28-30
[4] Akhmetov R T, Mukhametshin V V, Andreev A V and Sultanov Sh Kh 2017 Some testing results of productive strata wettability index forecasting technique SOCAR Proc. 4 pp 83-87
[5] Shakurova Al F and Shakurova Ay F 2018 The influence of hydraulic fracturing on the estimated ultimate recovery *IOP C. Ser.: Earth Env.* 194(8) 082039

[6] Almukhametova E M, Shamsutdinova G F and Petrova L V 2017 Analysis of the effectiveness of the methods used for the intensification of hydrocarbon production and enhanced oil recovery in the Fedorovskoye field using the example of object AS7-8 *Scientific Review* 21

[7] Yakupov R F, Mukhametshin V Sh and Tyncherov K T Filtration model of oil coning in a bottom water-drive reservoir *Periodico tche quimica* 15(30) 725-733

[8] Almukhametova E M and Gizetdinov I A 2018 Optimization of FPM system in Barsukovskoye deposit with hydrodynamic modeling and analysis of inter-well interaction 2 1015(3) 032006

[9] Almukhametova E M, Shamsutdinova G F, Sadvakasov A A, Tyncherov K T, Petrova L V and Stepanova R R 2018 Modeling development of Fyodorovsky deposit *IOP C. Ser.: Mat. Sci.* 327(4) 042100

[10] Mukhametshin V V and Andreev V E 2017 Search and argumentation of decisions aimed at increasing the efficiency of bottom-hole zone stimulation in oil accumulations with challenged reserves *SPE Russian Petroleum Technology Conf.* (Moscow: Society of Petroleum Engineers, 16-18 October 2017) p 23

[11] Ibragimov N G, Fattakhov I G, Kuleshova L S, Kadyrov R R, Sakhapova A K, Khamidullina E R 2011 New dedicated software determines water production behavior *Oil industry* [in Russian – Neftyanoye Khozyaystvo] 7 48–49