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First Successful Application of Multistage Fracturing Completion in Cased Old Vertical Well

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Abstract

Hydraulic fracturing has proven to be one of the most efficient and common completion methods to increase well productivity in mature oil fields with tight sandstone formations. However, the efficiency of the overall completion process is influenced not only by the applied fracturing technology but also by the well completion methods and production approach – especially in wells with long perforation intervals.

Nowadays, multistage fracturing systems have become widely used for more effective fracture placement and optimization of inflow profiles. This technology is mostly applied in on openhole section of horizontal wells where such completion requirements are most critical. However, the development of existing vertical wells can also benefit from the technology allowing selective stimulation of production zones, which could not be efficiently fractured otherwise. The approach described in the paper covers the candidate selection, recompletion technique, stimulation and production process applied for the oilfield in West Kazakhstan.

The sample well had been in production for several preceding years completed with perforations (up to 182 meters) at four main oil-bearing zones. Previously, there was done acidizing treatment which gave two-fold increase in production, but full potential of the well was not achieved. It was identified that the most of the inflow had been coming from only 43% of perforations while the rest intervals did not contribute to production. To achieve the coverage of all productive layers with fractures and involve all layers into production it was decided to recomplete the well with four-stage completion system with ball activated multishiftable frac sleeves.

Four stage completion system was installed in the cased old well and multiple fracturing stimulation was performed successfully. The job is a subject for further testing process of each treated zone, but the effectiveness of applied technology had already been proved as the overall production surplus more than four times. The operator considers replication of similar approach to the other wells in the oilfield.

Introduction

The development of the oilfield has started in 2003. In the technological scheme of development, based on the placement of productive layers, size and initial geological reserves, taking also into consideration physical and chemical properties of oils and geological and hydrodynamic characteristics, several layers were combined into one operational object, having a high coefficient of dismemberment.

As the experience of development of multi-layer objects shows, certain difficulties arise on the development stage of such objects. When several layers are combined into one object of development, the direct connection between the amount of liquid coming from the layers and their hydroconductivity is broken. In wells, where highly permeable and oil saturated layers join into single object, the latter, usually, do not drain or drain very poorly.

It has been shown that productivity factor rates (productivity on 1 m oilsaturated thickness) on multilayer's well objects had significantly below the average value than the wells, which were exploited on separate formations. This shows, that not all exposed oil reservoirs in multilayer formations work. Moreover, oil layers work asynchronously, i.e. oil production rate of them is different. As a result, separate oil layers are developed faster and, subsequently, the water inflows along into the producing wells, not displacing oil from porous medium thoroughly. This leads to decrease in the technological and economic efficiency of the development of an operational facility. Therefore, to regulate the production process, measures to introduce methods and technologies at the field were taken that would largely avoid negative consequences, associated with the project for massive-scale implementation of hydraulic fracturing.

Early fracturing jobs on producing wells of the field have been defined with various difficulties related to the placement of design fractures and the presence of uncertainties. Vertical wells with long perforation intervals in relatively thick formation have complicated the process of fracturing and raised the risk of placing sub-optimal quantity of the proppant into fracture.

Several attempts to place an optimal stimulation treatment have failed due to various factors like uncontrolled fracture growth in undefined zones, simultaneous development of multiple fractures, low fluid efficiency, low quality of the conducted jobs and the others. Multiple methods have been used to override the above-mentioned issues: reduction of the perforation intervals' length during workover and completion, high pumping rate and fluid viscosity during fracture initiation, application of the sand plugs for zonal isolation, minimal amount of the perforations and the others.

Most of the challenges were resolved through the implementation of quality control and engineering support of the stimulation process, but until today the task on complete zonal coverage of all productive intervals has failed (pic. 1 and 2).

Reviewing performed operations and their effectiveness, the option for applying the option of recompletion of wthe well with multistage fracturing system has been considered, which would allow to cover with treatment all productive layers. The job has been important not only for obtaining additional production, but also for unlocking the full potential of wells of the field, involvement in the production of all oil-bearing layers and conducting zonal flow testing and oil sampling at bottomhole conditions of each zone.

Technology of the multistage hydraulic fracturing

Multistage hydraulic fracturing – one of the most advanced technologies in oil industry, effective for vertical and for horizontal wells. The principal of the process of multistage stimulation is in serial of stages, cycle by cycle, of several hydraulic fracture treatments. In general, conducting multistage fracturing allows engaging into development all producing intervals, as well as those, which have not been involved since the completion of the well, and performing zonal oil sampling and flow testing after the stimulation. Certainly, important criteria of success has been the achievement of the planned additional production, which would allow to consider the technology implementation on other candidate wells.

After the technical analysis had been performed the system with ball activated fracturing sleeves designed for multiple frac stages in a well bore has been chosen.

This system has the following operational advantages:

1) High probability of initiation and development of fractures in the targeted intervals.
2) High flow circumferential ports located on the housing of the sleeve permits continuous communication to the reservoir for high pressure fracturing operations and production
3) The ability to control the development of fracture height, depending on frac design and its completion design.
4) The coverage of all productive zones with stimulation treatment and involvement into production.
5) Time reduction for treatment of several zones in sequence.
6) Specially designed anti-rotational features are incorporated into the sleeve to ensure reliable seat mill-out performance
7) Anchor system of the completion system allow rotating it during the launch

8) Packers are designed to ensure trouble-free launch and prevent accidental setting
9) Utilizing a designated shifting tool the valve sleeve can be closed to shut-off water producing intervals or for intervalproduction evaluation
10) The opportunity for additional downhole activities after treatment

System installation involves the usage of the special liner. The liner is equipped with sliding sleeves that are located opposite each of the intervals, isolated by annular packers. Hydraulic fracturing of these intervals is done in sequence, starting from the bottom of the well. This technology provides the options of stimulation operations in both cased and open hole completions. Operational algorithm provides several consecutive steps to open installed sleeves, starting from the lowest, which is activated by hydraulic pressure. Subsequent sleeves are opened by pumping and setting the different sized (from smaller to largest) balls into special landing seat.

The duration of the whole operation depending on the frac design may count for several days to several hours.

It is also important to note that the sliding sleeve mechanism provides the opportunity to operate their opening and closing with the special shifting tool. This design feature allows conducting both selective testing of each zone, as well as isolating those later on, in which the water inflow increase, thus increasing the productive period of the well.

A Field Application – Case 1

Proposed multistage fracturing completion system should have allowed conducting selective stimulation of zones i, ii, iii, iv (pic. 3) on chosen well. Candidate well has had suitable completion with production casing column 177,8 mm, which allowed to install multistage fracturing system and position in the area of existing perforations in 11 intervals with a total length up to 182 m (from which only 43% worked).

Also the selected well met the criteria on potential increase in production. Matrix acid stimulation was carried out on the well in 2017. An increase in oil production rate was received by 10 ton/day. Reviewing production parameters, the potential growth from fracturing has been determined. Respectively, the choice of the well met the profitability criteria of the potential growth. The cost-performance estimation of multistage fracturing with the use of MSF system has showed, that the PI after stimulation would be equal to 2,98 (above 1), which led to conclusion that the project should be cost-effective.

One of the main and crucial success factors of a multistage fracturing operation was the fracture growth control in isolated producing intervals in order to prevent interference between them, which could lead to uncontrolled loss of the treatment fluid and receiving undesirable complications. Based on lithology and petrophysical model, with involvement of the mechanical model properties, the assessment of fracture height expansion has been made (pic.3), which allowed developing optimal multistage stimulation design for the purpose of fracture retention in producing intervals, as well as ensuring the largest fracture half-length and stimulated reservoir volume. In order to get the high production rates the optimal intervals for sleeves' placement (in accordance with points of fracture initiation), the volumes of proppant and fracturing liquid (table 1) have been determined.

It is worth to mention that the additional attention has been paid to the risk assessment in design of fracturing treatment after the completion placement (OD 114 mm) in the cased hole (OD 178 mm) (pic. 4):

1. Throughout perforation of all production intervals
2. Increase of friction in the perforations and near wellbore zone due to the open space between completion liner and production casing

In this case, the high probability of friction increase during fracturing has been considered due to the complicated flow of treatment fluid and accumulation of proppant in the perforation intervals and space between casing and liner.

In order to mitigate the abovementioned risks the optimal intervals have been selected for reperforation (table 1) in the zones of sleeves' placement that should provide the decrease of friction and smooth treatment fluid flow in casing-liner space. The special attention to these risks should be paid during the data frac and main stage stimulation.

In connection with the above the production logging and survey of productive intervals, casing condition and zonal reperforations have been completed before the installation of completion liner.

Conducting the multistage fracturing

Fracturing operation on each of the 4 stages was conducted in following sequence:

1. The ball launch and setting into the sleeve seat with indication on the pressure graph (pic. 5)
2. Data frac (was conducted selectively – on 1st stage and 3rd in view of convergence of the layer conditions)
3. Main fracturing operation.

After conducting data frac, the data analysis and fracturing model have been adapted to the actual pressures, frac fluid effectiveness and other. Based on adapted model, the design of the main fracturing has been corrected. After the stimulation treatment, fracture models have been calibrated and adapted based on actual value of well-head pressure, resulting from main stage pumping. Fracture geometry calculations on adapted model has showed that interference fractures between intervals had not have happen. Also, the analysis indicated that the reperforation and sleeves' placement have decreased the risks related to the inter-column space between casing and liner.

Main fracturing stages have been completed without complications. Dynamics of indicators of main treatment are shown on pic. 6 and table 2.

On the last stage, having the goal of production increase, the technologies of putting well on production are applied for: performance evaluation of the project works, selection of completion system, determination of intervals for stimulation and distance between them, fracture parameters, their azimuth orientation etc. Well development methods largely depend on the chosen well completion system for multistage fracturing and, undoubtedly, involves the stages of well production survey and testing for determination of recommendations to optimize the abovementioned multistage fracturing design parameters and to select optimal well operation conditions after stimulation.

Analysis of the conducted works

As a result of successful multistage fracturing operation with the completion installation in a cased hole of a vertical well, all productive zones were covered: I, II, III, IV. The main result has been a four-time increase in production rate (pic.7). Analyzing well development stages after the multistage fracturing, the relatively high costs at the stage of the frac sleeve seats' milling process of the standard ball-drop completion. The involvement of the of coiled tubing to perform this type of work has been quite expensive due to the availability in the area. Also significant difficulties have arisen in conditions of low reservoir pressure – milling efficiency is greatly reduced due to the treatment fluid losses and additional formation damage. All of this significantly have slowed down the schedule of putting the well on production, reducing the potential and cumulative production.

To resolve this issue in the future it is proposed to use the completion with retrievable balls seats design. The retrieval of ball seats is possible either with the coiled tubing fleet, as well as workover contractor using standard technical equipment. Hence, securing full-passage inner liner diameter (fracturing sleeve) with cost minimization will eliminate the milling stage.

In order to control well's producing capacity and make decisions on the inflow from the different intervals, it is also necessary develop a solution to determine the inflow quality, for example the installation of tracer system in completion system for water production determination (separate tracer for each interval).

Generally, implementation of innovative technologies of re-completion of vertical well for selective stimulation and production is a confirmed solution for wells with several opened producing intervals and comingled production, recommended for further implementation in order to optimize development and increase production on Karatobe South field and similar oil and gas fields.

Conclusions

The successful recompletion of the well has shown that the multistage fracturing with installation of completion system in the cased hole of the existing vertical well is possible and it opens the new opportunities in development of existing brownfields with the wells with long productive intervals more than 100 meters.

The development of existing vertical wells can benefit from the technology allowing selective stimulation of production zones, which could not be efficiently fractured otherwise.

Four stage completion system with ball activated multishiftable frac sleeves has been installed in the cased old well and multiple fracturing stimulation has been performed successfully

The right approach for candidate selection, preparation works, application of quality technology of completion and multistage hydraulic fracturing have increased the probability of successful implementation on the oilfield in West Kazakhstan. The job outlined in the article has shown that the application of multistage completion system is effective not only in horizontal open hole wells but also in the old cased hole vertical wells and is the proven method for recompletion to increase the overall well life cycle.

The effectiveness of applied technology had already been proved as the overall production surplus more than four times. The operator considers replication of similar approach to the other wells in the oilfield. As the technology progresses, the applied design and methods will also be dealt with in the same systematic fashion.

Acknowledgements

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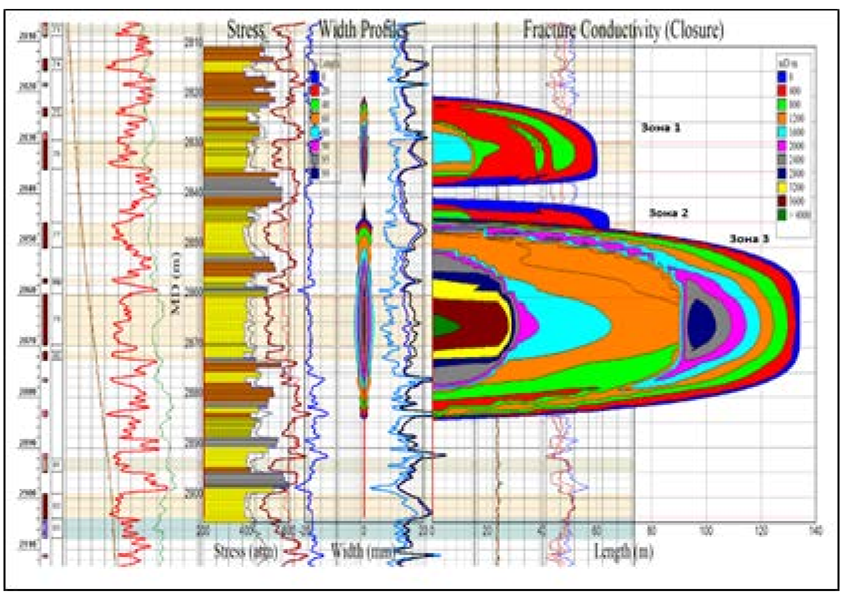
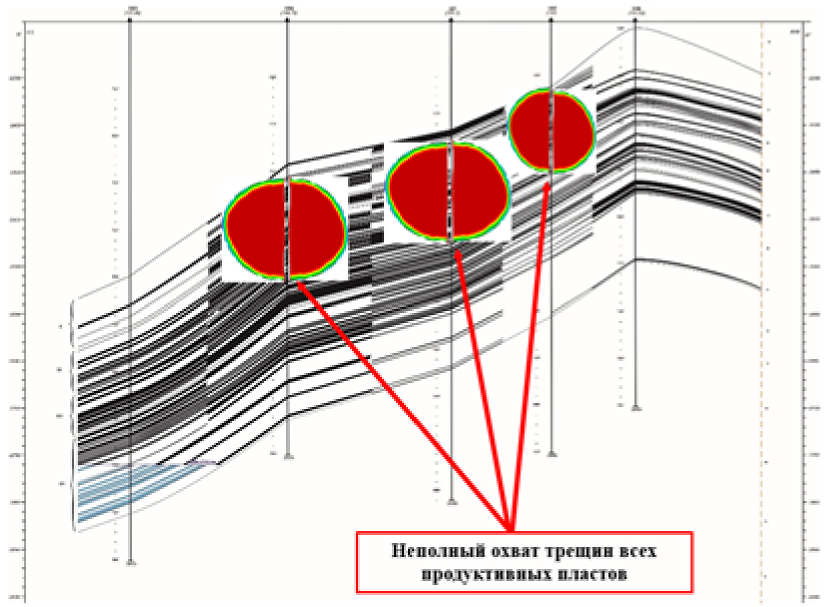
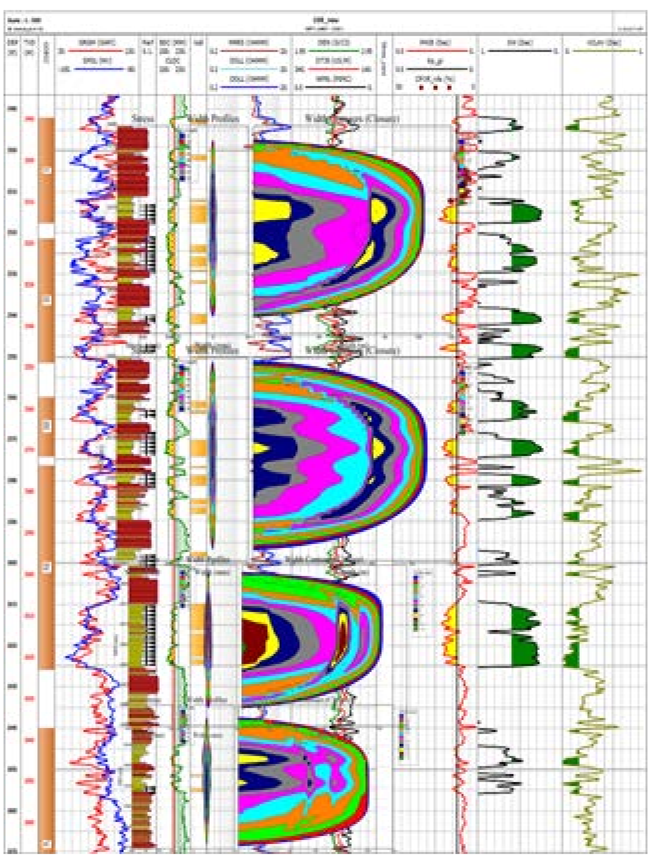
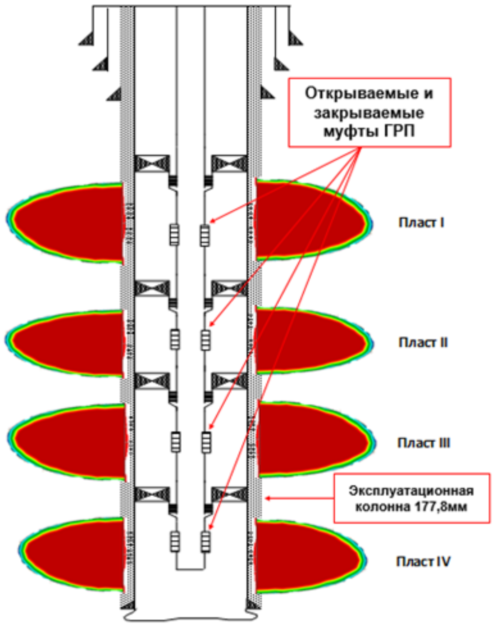


Pic. 1 – Fissure formation on extended perforations of multilayer horizons

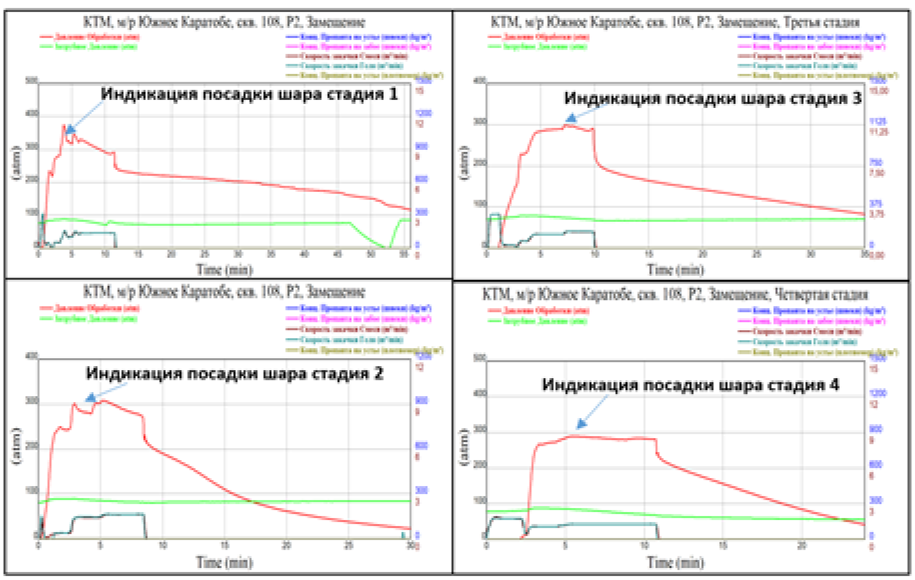


Pic. 2 – Fissure spreading of previously held FRACTURING

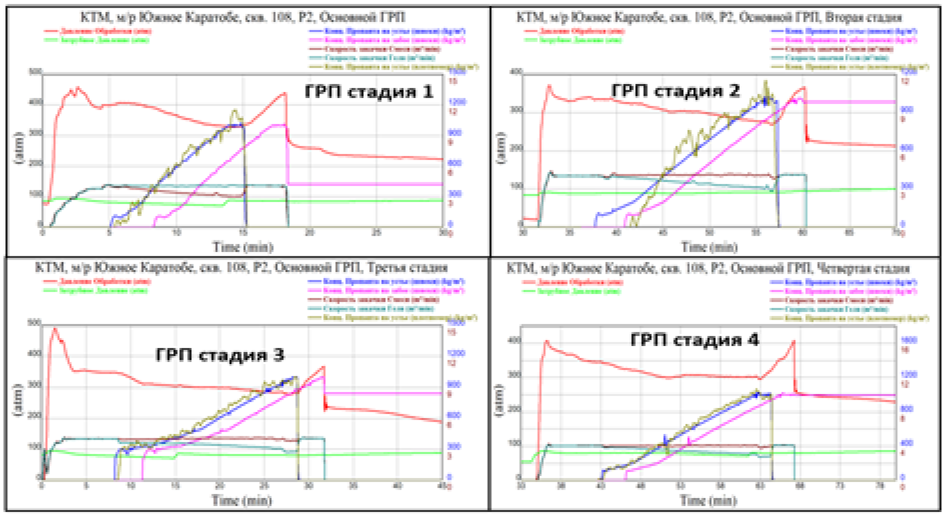

Pic. 3 – Project MULTISTAGE FRACTURING fissure profiles



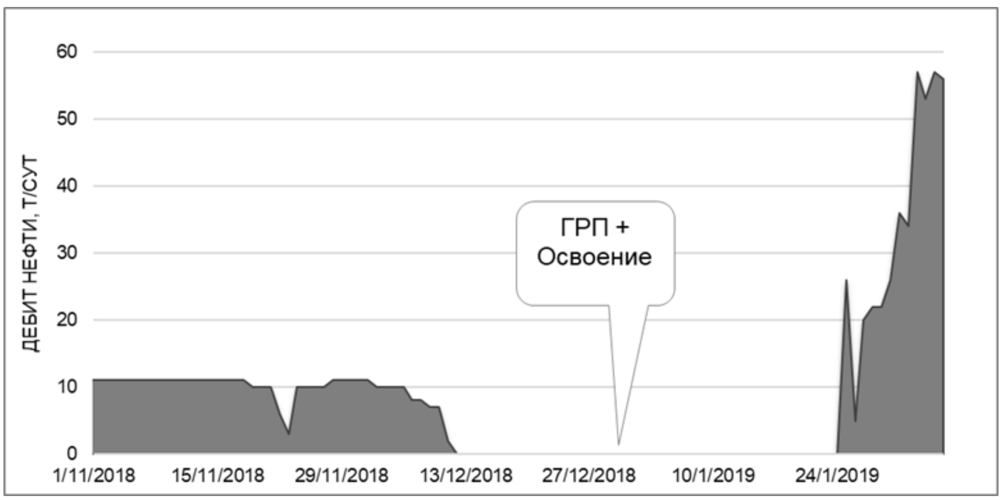
Pic. 4 – Well Schematic



Pic. 5 – Graphics indication of ball planting into muff saddle



Pic. 6 –FRACTURING Schedule



Pic. 7 – Oil production rate before and after MULTISTAGE FRACTURING

Table 1 – design parameters of MULTISTAGE FRACTURING

№ зоны	интервалы повторной перфорации, м			муфты ГРП, м
	кровля	подошва	мощность,	глубина
IV	2513	2517	4	2521
	2520	2530	10	
III	2563	2565	2	2573
	2568	2576	8	
	2578	2582	4	
II	2610	2616	6	2618
	2618	2626	8	
I	2644	2658	14	2650

Таблица 2 – параметры проведенных FRACTURING

Parameter	1 stage	2 stage	3 stage	4 stage
Proppant mass, tn	20 (16/30)	34 (16/30 – 30) (12/18 – 4)	40 (16/30 - 34) (12/18 – 6)	40 (16/30 – 34) (12/18 – 6)
Volume «подушки», m3	16	27	30	30
Total fluid volume, m3	106	114	157	129
Consumption, m3/min	4	4	4	4
Max. proppant concentration, kg/m3	1000	1000	1000	1000
МДОЗ increase , атм	32	-13	65	37